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The Influence of Silicon in Cast Iron.

THE IRON-CARBON-SILICON SYSTEM.

The influence of silicon in bringing about the decomposition of the combined carbon and the formation of graphite in iron-carbon alloys, and the consequent modification of the mechanical properties, shrinkages, and volume changes was first demonstrated by Prof. Turner in his now classical memoir presented before the Chemical Society.[1] As a result of the modification of the above physical qualities—properties which are vital to the ironfounder—the study of the influence of silicon in cast iron almost rivals in importance that of the influence of carbon.

Commercial cast iron absorbs silicon during its production in the blast furnace, and various amounts of this constituent are contained in the different brands of pig-iron. The product of the modern hot-blast furnace usually contains from 1.50 to 2.50 per cent., and as high as 5 per cent. silicon. True, cold-blast pig-irons are invariably much lower in silicon than hot-blast irons. The following table contains the typical analyses of some of the well-known types of British pig-iron.

TABLE I.

	Charcoal cold blast.	Cold blast	Semi-hot blast.	Hot blast No. 1.	Silky.
C. C.	0.80—	—	.75	0.01	—
Gr.	3.25—3.50	2.81—3.25	3.10	3.41	—
Tot. C.	4.05—3.50	—	3.85	3.42	3.45
Si.	0.80—0.25	0.60—1.50	1.50	2.95	4.50
Mn.	0.12	0.15—0.75	0.75	0.50	0.61
S.	0.015–0 50	0.06—0.03	0.04	0.036	0.070
P.	0.08—0.10	0.29—0.50	0.50	1.65	1.60

Special high silicon alloys are also frequently prepared in the blast furnace by modifying the character of the burden and the working of the furnace. These high-silicon alloys contain as much as from 10 to 50 per cent. of silicon, and are usually known as ferro-silicon. On fracturing these ferro-silicon alloys they are found to possess a white, hard, glistening fracture, and on this account they are classed along with other ferro alloys as belonging to the speigel family. (Speigel-Glistening. Ger.)

During recent years it has been shown that high-silicon iron alloys withstand the corrosion of acids and other chemical liquors; and on this account large quantities are now being used for the manufacture of chemical-works plant. A typical analysis of one of the trade products of this material, which goes under various names such as Tant-iron, Iron-Ak., etc., is as follows:—Cc. 0.47 per cent., Gr 0.10 per cent., Tot C 0.57 per cent., Si 15.43 per cent., Mn 0.64 per cent., P 0.44 per cent. This material is prepared by melting high-grade ferro-silicon and pig-iron in the ordinary foundry cupola. It is hard and unmachinable, and special care has to be taken in allowing the castings to cool down slowly to prevent cracking due to excessive shrinkage.

Binary Iron Silicon Alloys.—The constitutional diagram of the simple binary iron-silicon system has been constructed by Messrs. Guertler and Tamman[2]. The addition of increasing quantities of silicon to pure iron was found to result in the gradual diminution of the freezing temperature till at a temperature of 1,250 deg. C. and a concentration of 31 atoms per cent. (" 18 per cent. by weight") the alloy is indicated to solidify as the chemical compound Fe_2 Si. In the whole range of alloys up to this concentration the silicon is regarded as existing in solid solution as the above chemical compound. Considerable doubt still surrounds the identity of the chemical compound. A slightly different interpretation of this portion of the diagram is utilised by Gonterman. He assumes that the composition of the 31 atoms per cent. silicon alloy closely approximates that of the solid solution. The point B corresponds to the temperature and concentration of the formation of the eutectic of the saturated solid solution, and the chemical compound Fe. Si. A slight alteration in the diagram is therefore necessary, and the modified diagram is illustrated in Fig. 1, the point I, corresponding to the saturated solid solution of the compound Fe. Si. Our knowledge of the influence on the allotropic transformations in iron is still somewhat uncertain. This fact is due largely to the influence of silicon in causing the transformations to proceed with such slowness as to be incapable of detection by the means at our disposal. Osmond showed in a sample of iron containing 0.14 to 0.25 per cent. of carbon that the presence of 0.2 per cent. silicon weakens very considerably the strongly marked Y to B recalescence, and in alloys containing 2.7 per cent. of this element this point was only just noticeable. With a further increase in silicon, all trace of the point entirely disappears. The experiments of Osmond Arnold and Baker all agree that the Ar2 point is lowered about 7 to 8 deg. C. for each 1 per cent. of silicon present in the alloy. Guertler and Tamman, however, state that this point is not materially affected by the presence of silicon although their figures show a slight reduction in the temperature at this point. The recent work of Andrew in connection with alloys containing a considerable proportion of carbon, appear to con-

[1] Journal Chem. Soc., Vols. xlvii and xlix.

[2] Z.A.C., Vol. xlvii p. 163.

clusively show that the temperature of the Ar2 point is gradually raised with increasing quantities of silicon. It is very important to note that the occurrence of the Ar2 point in the 31 atoms per cent. alloy is strong argument in favour of the assumption that this alloy is the saturated solid solution and not a chemical compound.

The assumption that silicon is perfectly soluble

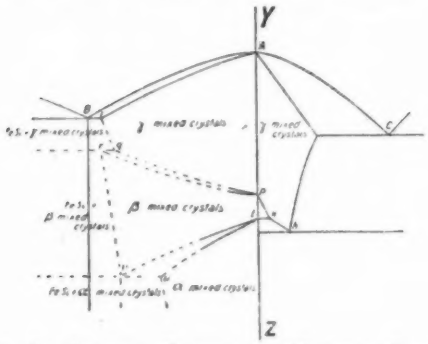

FIG. 1.—SHOWING PORTION OF MODIFIED BINARY IRON-SILICON SYSTEM.
(*Gonterman, J.I.S.I., Vol. I.*, 1911.)

in both β and α modifications of iron is fully confirmed by the work of Baker.

The modified binary diagram of Guertler and Tamman was utilised by Gonterman in the construction of the ternary iron-carbon-silicon system. The transformations, as far as they are reliably known, are indicated by the thick lines in Fig. 1, the dotted lines are more or less hypothetical, and serve to indicate the probable course that these transformations pursue in the higher-silicon alloys.

It is important to note from this work that the silicon up to a concentration of 31 atoms per cent. exists as a solid solution of the chemical compound Fe_2Si in iron. In this condition the silicon, of course, cannot be separately identified under the microscope.

Iron-Carbon-Silicon System. Ternary Alloys.—The Ternary iron-carbon-silicon system has been systematically investigated by Gonterman.[3] An enormous amount of work has been done by other workers on the addition of silicon to iron carbon alloys which are strictly investigations of a restricted portion of the ternary system. For our knowledge of the influence of silicon on the iron-carbon system we are indebted to Turner, Hague, Wust, Hatfield, Stead, Charpy, Andrew, and others. In that it is the only attempt to diagrammatically represent the constitution of the ternary alloys the work of Gonterman is of immense importance. In many respects the course of the changes, as indicated in this work, particularly in the solid alloys, is purely hypothetical. The diagram, however, is of considerable value in that it allows of a more advanced qualitative view of the influence of silicon on the binary iron carbon system.

It was originally demonstrated by Dr. Stead[4] that in the ternary system of iron-carbon-silicon two series of solid solutions are formed, viz.: a solution of carbon and silicon in and a solution of silicide of iron in the carbide of iron. Consequently, in their behaviour on solidification the ternary alloys closely resemble the binary iron-carbon system. Indeed, subject to certain alterations, the description of the solidification of the binary system applies to the ternary system by substituting the terms silico-cementite and silico-austenite for cementite and austenite respectively.

A view of the space model of the ternary system is shown in Fig. 2. The upper or liquidus surface is practically completely visible, and the solidus surface is partially visible on the underside, the vacant space corresponding to the range of stability of the homogeneous silico-austenite solid solutions. A projection of the surfaces of the model on the base triangle is illustrated in Fig. 3, and for further guidance the two bounding binary systems are attached lying flat in the plane of the paper. The binary iron-carbon system has been drawn to four times the scale of the binary iron-silicon system. In this model the curve B C, B^1C^1 in the projection, joining the 4.3 per cent. binary iron-carbon eutectic and the 22 per cent. silicon eutectic, indicate the temperature of the simultaneous crystallisation of the saturated silico austenite and the silico cementite occurs on solidification. This curve was experimentally determined by Gonterman by plotting the concen-

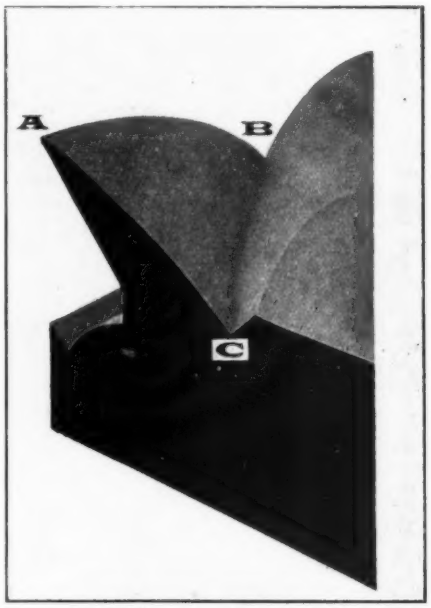

FIG. 2.—SPACE MODEL OF TERNARY IRON-CARBON-SILICON SYSTEM.

trations of the ternary alloys, of which the liquidus and solidus temperatures were the minimum distance from each other. The concentrations of these alloys will be sufficiently close to the true position of B C for all practical purposes. No ternary eutectic point was found.

The values obtained by Gonterman for the line B C are given in Table II. These results are in close agreement with a similar series of figures obtained by Wust,[5] and the temperatures within

[3] J.I.S.I., 1911, Vol. ii.
[4] Brit. Assoc. Sheffield, 1910.
[5] Metallurgie, Vol. iii. pp. 811-820.

limits imposed by the experimental method correspond to the H arrest for the iron-carbon-silicon obtained by Hague and Turner.[6]

TABLE II.

Silicon per cent.	Carbon per cent.	Temp. °C.	Silicon per cent.	Carbon per cent.	Temp. °C.
0.0	4.30	1130	6.0	2.55	1168
0.9	3.92	1143	6.7	2.20	1140
1.6	3.75	1150	8.6	1.88	1153
2.0	3.63	1165	9.6	1.67	1148
3.0	3.30	1160	12.5	1.10	1179
4.1	3.06	1162	16.0	0.74	1175

The reduction in the solubility of the carbon by the presence of silicon in these alloys is readily apparent from these figures. In the ternary alloys containing from 2 to 3 per cent. of silicon a very frequent commercial percentage, the percentage of carbon corresponding to equilibrium is from 3.63 to 3.30 per cent., the gradual increase in the freezing temperature is readily appreciated from the slope of the curve B C, illustrated in Fig. 4.

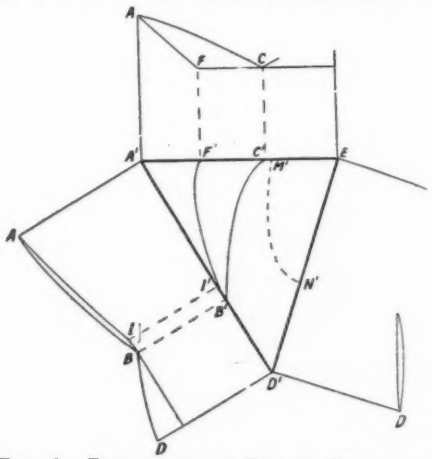

FIG. 3.—PROSECTION OF SOLIDAS SURFACE OF TERNARY ALLOYS.

All those ternary alloys whose composition lies within the boundaries of the liquidus surface A B C on cooling from the molten state, deposit crystals of silico austenite, the solid solution of carbon and silicon in γ iron. To the right of the line B C in the figure the silico cementite is the first to be deposited on solidification. Solidification is complete at the temperature denoted by the solidus surface shown in part in Fig. 2, the liquidus and solidus planes meeting the respective binary sides of the prism in the liquidus and solidus curves respectively. The line F I joining the respective binary saturated solid solutions, represents the temperature and concentrations of the saturated ternary solid solutions. These concentrations were determined by Gonterman as the points of intersection of the horizontal lines drawn from the ends of the liquidus curves with the continuation of the solidus plane.

Solidification of the Ternary Alloys.—The diagram, as constructed by Gonterman, was admittedly only tentative, and at the most can only be utilised qualitatively. On these grounds therefore it will only be considered here in so far As it is concerned with these ternary alloys whose chemical composition lies within the range of commercial cast-iron. Owing to the method of manufacture of commercial cast-iron in the blast furnace it will readily be perceived that the concentration of the ternary alloys with which we are

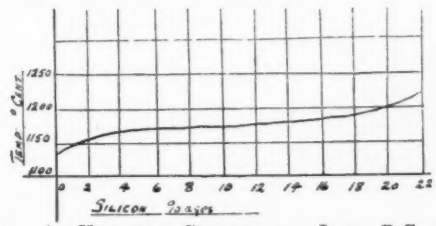

FIG. 4.—VERTICAL SECTION OF LINE B.C. IN TERNARY IRON-CARBON-SILICON DIAGRAM, SHOWING INFLUENCE OF SILICON ON FREEZING TEMPERATURE.

more nearly concerned will lie either on the line B C or in close proximity on either side of it.

Consider an alloy whose composition lies within the austenite area of the diagram. This alloy on cooling down from the molten state meets the liquidus surface A B C at the point A in Fig. 5 and commences to deposit crystals of silico austenite solid solution. The concentrations of the primarily deposited silico-austenite solid solutions are represented by points lying on the solidus surface A F I. Before these can be quantitatively determined it is necessary to know the direction of the conjugation or tie lines. The experimental determination of the course of these lines is fundamental to a complete quantitative conception of the ternary system. In the hypothetical case under consideration the point Ak is assumed to

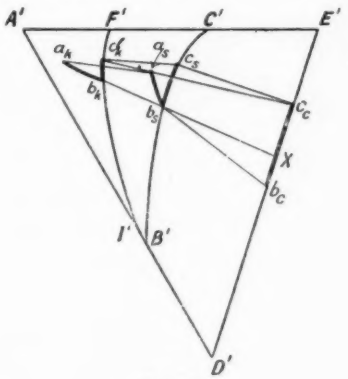

FIG. 5.

represent the temperature and concentration of the first crop of crystals deposited at the commencement of the Alloy As.

On further cooling, the molten liquid continues to deposit further quantities of crystals, the concentration of which move along the hypothetical curve ak, bk. The concentration of the mother liquor remaining at each stage of the solidification in equilibrium with the deposited crystals in a like manner is assumed to move along the curve as, bs.

[6] J.I.S.I., 1910.

If, as in the hypothetical case the alloy contains a concentration of silicon and carbon in excess of that corresponding to the limit of saturation, in other words, if the composition of the alloy falls within the area F I B C, then the deposited silico austenite crystals must reach a limit of saturation at a period during solidification. This point is indicated in the figure, and the curve ak, bk is shown to intersect the curve F I at the point bk. The composition of the still remaining portion of the molten metal in equilibrium with the deposited crystals at this point is indicated by the intersection of the curve a.c., b.s. with the line B C. From this point both the solid solution and the molten metal commences to deposit silico cementite, and the composition moves along F I and B C in the direction of F and C respectively, until the last drop of molten liquid is used up, and the alloy solidifies as a whole, consisting of silico austenite and silico cementite. It has already been noticed in the case of the binary iron-carbon system, that the composition of the deposited phases continually varies, and equilibrium is assumed to be established consecutively with the freezing by a process of diffusion. This is likewise the case in the ternary systems, and comparatively slow rates of cooling are necessary in order that complete equilibrium may be established. In actual industrial cases it is extremely probable that consequent upon the comparative rapidity of the cooling, equilibrium is never fully established in this manner. This results in the composition of the deposited primary crystals varying in silicon and carbon from the centre to the outside. The complexity of the reactions is further increased owing to the enveloping of the primary crystals with successive layers of a higher silicon and carbon content material, and these primary crytals are withdrawn from the reactions bringing about in effect a change in the total composition of the alloy.

Consequently, the commercial alloy may undergo changes which do not correspond to strict conditions of equilibrium.

In those alloys whose composition falls within the silico cementite range to the right of the line B^1 C^1 in Fig. 5, it may be considered that silico cementite is the primary phase to crystallise out on solidification. Very little is known concerning this portion of the system, and it will be dealt with at some length in a subsequent portion of the diagram.

Transformation in Ternary Alloys of Iron-Carbon-Silicon.—The influence of silicon on the critical transformations of the iron-carbon-system has been investigated by several workers. The thermal data, including the H3 point (pearlite point) on a complete series of iron-carbon-silicon alloys, as determined by Hague and Turner are included in Table III. In view of more recent work it is important to note the indications in most of these cooling curves of an additional arrest between the temperatures of 800 deg. and 900 deg. C. The results obtained by Gonterman are practically confirmed by these authors, and the slight disparity in the actual temperatures of the arrests may be attributed to experimental error due to the small quantities of alloys utilised in the former experiments. From the fall in temperature of the H, arrest point, Hague and Turner calculate that the liquidus curve would meet the eutectic line with about 7 per cent. of silicon. This is a somewhat higher percentage than that given in Gonterman's determination. The raising of the lowest arrest point, H_2, with increasing quantities of silicon, obtained by Hague and Turner, was also noted by Gonterman. From 0 to 5 per cent. silicon the temperature is raised from 700 deg. to 800 deg. C. These temperatures are in substantial agreement with those obtained by Gonterman.

TABLE III.

No. of Bar.	Fracture.	Silicon.	Total. Carbon.	Graphitic Carbon.	Combined Carbon by diff.	Temperature Arrests.			Other Arrests.
						H^1 (°C)	H^2 (°C)	H^3 (°C)	
		per cent.	per cent.	per cent.	per cent.				
1	White	0.03	2.71	0.16	2.55	1245	1138	700	Indication in most cooling curves between the temp. 800° C to 900°C of a slight arrest, corres. to bend in extens. curve before the bending corres. to H31.
2	,,	0.23	2.61	0.17	2.44	1217	1138	714	
3	,,	0.66	2.95	0.13	2.82	1244	1136	726	
4	,,	0.97	2.56	0.23	2.33	1247	1136	730	
5	Grey	1.19	2.70	1.32	1.38	1244	1136	734	
6	,,	1.50	2.48	1.29	1.19	1230	1137	739	
7	,,	1.95	2.47	1.50	0.97	1246	1141	746	
8	,,	2.18	2.54	1.50	1.04	1213	1146	752	
9	,,	2.43	2.54	1.51	1.03	1243	1146	752	
10	,,	2.77	2.67	1.47	1.20	1238	1148	754	
11	,,	2.80	2.51	1.48	1.03	1245	1153	764	
12	,,	3.06	2.77	1.93	0.84	1202	1154	774	
13	,,	3.47	2.79	1.87	0.92	1195	1158	780	
14	,,	4.03	2.34	1.55	0.79	1220	1160	774	
15	,,	4.43	2.41	1.75	0.66	1201	1160	786	
16	,,	4.83	2.26	1.62	0.64	1211	1161	795	
17	,,	3.00	2.62	2.40	0.22	1210	1146	687	

The recent experimental work of Andrews[7] would appear to modify the conclusions to be drawn from the above. In this work it is shown that the magnitude of the thermal change corresponding to the pearlite arrest is rapidly decreased with success in additions of silicon, until at 4.5 per cent. of this element the pearlite arrest is entirely absent. On the other hand, the Ar 3.2 point, indicating the β to α change is gradually raised with increasing quantities of silicon. According to Andrews it is probable that with as much as 10 per cent. silicon the temperature of this point is raised to the freezing point. This would indicate that in such an alloy the α (Alpha) iron is

[7] Carnegie Memoirs, 1917, J.I.S.T.

deposited immediately upon solidification. From this work it would appear that in both the previous-mentioned researches the Ar 3.2 point has not been separately identified, an assumption which is justified on consideration of the methods used in taking the curves.

The Formation of Graphite in the Ternary Alloys of Iron-Carbon-Silicon.—The influence of silicon in promoting the formation of graphite in cast iron has been repeatedly shown, and on this account further consideration of the transformations in these ternary alloys must of necessity be considered in connection with the formation of this constituent. There is no doubt that the phases separating out of the ternary alloys immediately on solidification, are silico, cementite, and silico austenite, in those alloys whose composition lies within the area F.I.B.C., and also slightly to the right of line B C. The whole of the commercial cast irons are covered by this statement. This was first conclusively demonstrated by Dr. Stead in his address before the British Association previously mentioned, and has subsequently been experimentally demonstrated by Andrews. The cooling curves and photomicrographs of the latter worker fully confirm this fundamental fact, and it is further stated that the deposited Silico Cementite is stable for a considerable range below the solidification point down to a temperature which, though undertermined, is probably in the region of 1,100 deg. C.

The precipitation of graphite in the ternary alloys must therefore be considered to take place below the temperature denoted by the plane F I B C in the solid ternary model. In all the ternary alloys the magnitude of the period of the final soldification arrest is greater than in the corresponding binary alloys. This is noticeable in the curves given by Andrews, and also it is apparent in the curves of Hague and Turner. The increase in the magnitude of the H_2 arrest is very pronounced in those samples in which large quantities of graphite have been deposited. The prolongation of the thermal change at this point in the ternary alloys is considered to be brought about by the precipitation of the graphite upon the dissociation of the primary carbide immediately following solidification. If this were not the case there would surely be some evidence on the freezing curve of the actual temperature at which the carbide did dissociate. Under perfectly stable conditions the whole of the carbon in pure binary iron-carbon alloys must be considered as being in the free or graphitic state, and it will therefore be readily appreciated that the influence of silicon in the ternary sysetm largely consists of increasing the

TABLE IV.

	CC. before treatment. per cent.	CC. after treatment. per cent.
White iron treated above	3.50	3.44
White iron treated with ferro-silicon	3.20	0.60

tendency towards the stable form. It is generally considered that the influence of silicon in this connection is exerted through its influence in promoting the instability of the carbide constituent. Dr. Stead heated together in an atmosphere of nitrogen crushed white iron and ferro-silicon, and by this means obtained almost total precipitation of the carbon. The results obtained are given in Table IV.

TABLE V.

	CC.	Gr.	Si.	Mn.	S.	P.
A.	3.62	Nil	1.20	0.18	0.011	0.041
B.	3.20	Nil	0.81	0.14	0.010	0.04
C.	3.40	Nil	0.85	2.66	0.012	0.041
D.	3.16	Nil	0.97	0.04	0.45	0.04

In a like manner, Hatfield[8] separated the carbide electrolytically from cast irons of varying silicon content, and in various states of heat-treatment. On analysis of the separated carbides, the results are indicated in Tables V. and VI.

These experiments are cited to show that a considerable proportion of the silicon exists with the carbide residue, and to prove the natural inference that the instability of the carbide is due to its presence. The exact mechanism of the influence of silicon in this connection is, however, undetermined.

The heat-treatment experiments of Charpy and

TABLE VI.

Bars quenched at 740° C.	Analysis of carbide.			Normal bars.	
	Si. %	Mn. %	C %	Si. %	Mn. %
A.	1.09	0.19	6.79	2.15	0.28
B.	0.61	0.16	6.40	1.01	0.19
C.	0.15	3.74	7.20	1.45	3.62
D.	0.37	traces	6.60	0.49	traces

Grenet[9] and other collaborators fully confirm the view that the silicon is responsible for the instability of the carbide, and in a later research Charpy and Thenard show that with a percentage of 3 per cent. silicon and a suitable rate of cooling, the complete decomposition of the carbide in steels can be brought about within a certain temperature zone. Further, the influence of silicon on the rate of reaction is such that in certain irons the graphite precipitation gives rise to a thermal point which may co-exist with the A.I. point, and possesses special sharpness when the latter has disappeared. It is important to note that these latter authors were unable to bring about the dissociation of the carbide with less than 3 per cent. silicon in steels.

Careful experiments have been made by various workers into the relative amounts of free carbon deposited with a gradual increase in silicon content. It will be fully appreciated that experiments with this end in view are extremely difficult, since it is imperative that other factors which influence graphite precipitation, of which there are many, should be either eliminated or maintained constant throughout the experiments. This is a very difficult thing to do. The most reliable data we have at present are the results of a series of careful experiments by Dr. W. H. Hatfield. In these experiments, the results of which are given in Table VII., every care was taken to ensure that the casting temperatures and the rates of cooling

[8] Hatfield, A., Vol. lxxxv., 1911.
[9] Engineering, 1902.
[10] J.I.S.I., 1915, Vol. i.

were constant. The size of the bars as cast was 12 in. × 1 in. × ⅜ in., from which it will be seen

TABLE VII.

No.	CC per cent.	Gr per cent.	Si per cent.	Remarks.	Fracture.
7	2.9	trace	0.28	Manganese,	White
8	2.9	,,	0.53	not exceed-	,,
9	2.9	,,	0.63	ing 0.20%.	,,
10	2.9	,,	0.66	Sulphur,	,,
11	2.9	,,	0.88	not exceed-	,,
12	2.9	,,	0.99	ing 0.05 %.	,,
13	3.0	,,	1.10	Phos-	,,
14	2.7	0.28	1.43	phorus	Trace Mottled
15	2.3	0.65	1.68	not	Mottled
16	0.6	2.47	1.72	exceeding	Grey
17	0.55	2.6	1.80	0.05 %.	,,
18	0.55	2.68	1.96		,,
19	0.5	2.75	2.07		,,
20	0.5	2.75	2.19		,,
21	0.49	2.8	2.36		,,
22	0.48	2.85	2.50		,,

that the bars were quite thin castings. From the results given in the table it will be quite evident that the precipitation of free carbon does not take place gradually with the gradual increase of silicon content. Up to 1.43 per cent. silicon, only a small quantity of graphite, 0.28 per cent., has been precipitated, and on slightly increasing the silicon percentage to 1.72 the extent of the carbon precipitation increases to 2.47 per cent.

In the experiments of Hague and Turner, tabulated in Table I., a somewhat similar effect is noticeable though not so marked. With an increase in silicon content of from 0.97 to 1.19 per cent. the extent of the carbon precipitation increases from 0.23 to 1.32 per cent., and quite large increases in silicon content beyond this point do not produce any further precipitation of free carbon. The size of the bars used in these experiments was 12 in. × 1 in. × 1 in. These experiments conclusively demonstrate the influence of silicon in bringing about the precipitation of the carbon under the particular conditions of the experiments.

A complete theory of the mechanism of the influence of silicon in promoting the dissociation of the carbide is not possible without the knowledge of the mode of existence of the silicon in the alloy. It has already been fully pointed out that at present we have no means of knowing this quantitatively.

Although the position of the line F.I. of the ter-

TABLE VIII.

Carbon per cent.	Silicon per cent.
2.0	0
1.90	0.9
1.75	2.0
1.50	3.0
1.25	4.0
1.00	6,0

nary saturated solid solution was not absolutely fixed by Gonterman, the compositions represented by this line are sufficiently approximate for industrial purposes, and are given in Table VIII.

The composition of the saturated solid solution deposited by any given ternary alloy will depend entirely on the course taken by the conjugation lines. In so far as industrial cast-iron alloys are concerned, we are justified in taking Dr. Stead's assumption that in all but low silicon alloys a portion of the silicon crystallises out with the carbide. It is extremely probable that the point at which a small increase in silicon produces a rapid deposition of free carbon, as noted above in the experiments of Hatfield and Hague and Turner, represents the point at which in the particular alloys investigated, and under the conditions of the experiment, the percentage of silicon had been sufficiently high to allow of some crystallising with the carbide. It is also important to note that in Hague and Turner's experiments it is about this point that the widening of the solidification range on the cooling curve begins to be noticeable. The silico-carbide crystallising out on solidification, following on the assumption made in connection with the binary system, may be assumed to be unstable at some temperatures below solidification point, and consequently decompose into silico austenite and graphite. With the gradually falling temperature the silico austenite further throws out of solution the excess silico cementite, which further decomposes in a like manner.

The recent work of Andrews has brought forth additional facts likely to throw considerable light on the mechanism of the influence of silicon on the condition of the carbon in the ternary alloys. In this work Andrews shows that the raising of the has been mistaken for the Ar 3.2. point. With the addition of 4.50 per cent. silicon in his experiments he found that the pearlite point was practically absent, and the Ar 3.2. point, which had become considerably more prominent, had risen to such an extent that he calculated with somewhere in the region of 10 per cent. silicon it would practically be coincident with the solidification point. This would indicate in such alloys that γ modification would immediately be deposited upon solidification, and in all probability the carbon would therefore be wholly deposited in the graphitic form. Practical confirmation of this theory is to be found in the case of the high-silicon non-corrodible alloys mentioned at the commencement of this chapter. In these alloys, which contain 15 per cent. and over of silicon, and which are made by the addition of ferro-silicon to foundry pig-iron, the extent of the total carbon in the final alloy is only very small, of the order of ½ per cent., a fact which points to the decomposition of the whole of the carbide previous to and during the solidification range. This graphite, on account of its low specific gravity, rises to the surface of the molten metal, and consequently the final alloy is practically free from carbon.

The second important point brought out in this work is that by heating the alloy to a high temperature a double freezing point is thereby created, as illustrated in the curve, Fig. 6. The same effect is brought about by primarily melting the alloy and quenching it. This is considered by Andrews to be due to the primary crystallisation of the silico cementite. Dr. Stead has been able to distinguish between the silico cementite and plain cementite by the different colours assumed on heat treating. This effect, however, may have considerable bearing upon the ultimate explanation of the precipitation of graphite in very low silicon hot-blast pig-irons, which are from time

to time accidentally met with. The importance of these results will be readily apparent, and further confirmation of the data is still awaited.

Summing up the influence of silicon on the transformation after solidification in the ternary alloys is considerably modified by its influence in causing the precipitation of free carbon. As a result of this the extent of the pearlite point is modified, and under normal conditions of rate of cooling vanishes with about 4.5 per cent. silicon. It must always be borne in mind that the influence of silicon is considerably enhanced by the rate of cooling, and theoretically the pearlite point is entirely absent in the perfectly stable binary system. The Ar 3.2. point according to Andrews is gradually raised with increasing percentages of silicon till at 10 per cent. silicon it is in all probability coincident with the solidification point. This is in agreement with the work of Charpy and Thenard, conducted on the low-carbon content ternary alloys.

The increase in magnitude of the thermal arrest with certain percentages of silicon probably corresponds to the dissociation of the carbide constituent with the solid solution and free carbon.

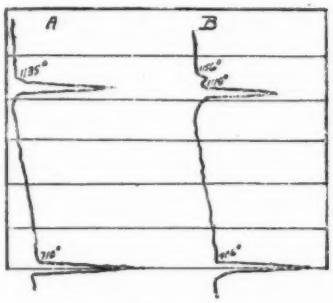

FIG. 6.

The dissociation continues in the silico carbide deposited from the solid solution during further cooling, and the completeness of this secondary dissociation depends, firstly, on the rate of cooling and on the silicon content of the solid solution. Quantitative conceptions of this reaction are not possible in view of the absence of complete quantitative data concerning the conjugation lines in the ternary diagram.

In industrial cast-irons it has already been pointed out that during cooling it is extremely probable that equilibrium conditions are not strictly adhered to. The effect of this has already been explained. Its influence is of far greater importance in the ternary alloys containing silicon than in the simple binary iron-carbon system. This will readily be apparent when it is considered that by this means the silicon-content of portions of the alloy can be artificially raised, and consequently the formation of graphite may be inaugurated, and take place more rapidly than would be expected in the normal alloy.

With regard to the formation of graphite in those alloys lying to the right of the eutectic line still less is known than in the case of the binary series. For a short range, it may be considered that silico cementites are deposited, and that these dissociate with considerable rapidity according to the rate of cooling.

Foundry Considerations.—The influence of silicon in bringing about this dissociation of the carbide is of very considerable value in everyday foundry practice. It is essential in considering this much-debated question of the influence of silicon in this connection, to bear in mind the fact that the success of grey cast iron as a medium for the production of castings (apart from financial considerations) is due entirely to its low shrinkage coefficient. This fact is wholly due to the dissociation of the carbide into the more bulky phase graphite. Providing the rate of cooling of the alloy is sufficiently slow, this dissociation will take place in its entirety in a pure iron-carbon alloy in the absence of silicon. In by far the greater majority of castings made in the iron-foundry, the rate of cooling is not nearly sufficiently slow to allow a dissociation of sufficient magnitude to reduce the shrinkage to a minimum value, and to render the alloy sufficiently soft for machining purposes. On this account therefore the presence of silicon is absolutely necessary in the production

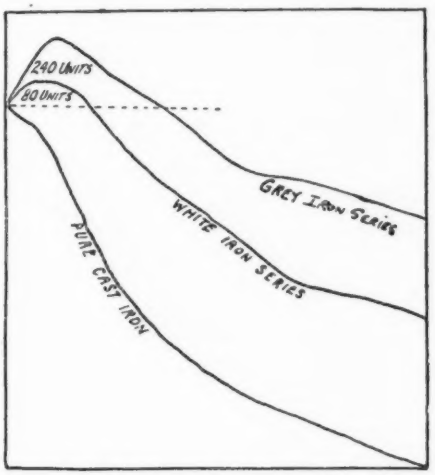

FIG. 7.—EXPANSION CURVES OF CAST IRON. (*Turner, J.I.S.I.*, 1910.)

of castings, and obviously a larger amount of silicon will be necessary in order to produce the same result in an extremely thin casting in which the rate of cooling is very rapid than in a thicker casting.

The influence of silicon on the expansions, as measured by Turner's extensometer method, have been investigated by Hague and Turner. Their results are shown in the diagram Fig. 7. In these results it will be noted that a bar of pure washed iron contracts uniformly throughout the cooling. Immediately on the addition of only 0.23 per cent. silicon a marked expansion of 80 units becomes evident immediately after solidification. This primary expansion is practically constant so long as the bar remains white. Immediately on the formation of graphite, the magnitude of this expansion is increased by 160 units to 240 units, and the time interval is more than doubled. The occurrence of the primary 80 units expansion in the white-iron series is difficult to explain. It is ascribed by Turner to the formation of a more complex solid solution. The secondary expansion occurring immediately after solidification confirms the conclusion drawn from the cooling curves that

the graphite is precipitated immediately after solidification, and continues over an extended time interval.

The influence of silicon in the shrinkage is made amply apparent by these results. It will be seen from the results of Hatfields, and also the above-mentioned investigators, that the maximum graphite precipitation is rapidly attained with a small increase in silicon above a figure of about 1.5 per cent. A full appreciation of these figures will lead one to the conclusion that there is no necessity for the oft-times elaborate systems of silicon control evolved by certain authors.

New Year Honours.

The list of New Year honours issued on January 1 is noteworthy by reason of the recognition of special war services. The Right Hon. Sir Albert Henry Stanley, M.P., late President of the Board of Trade, is created a Baron. The following appointments to the Order of the Bath are notified:—G.C.B.: Right Hon. Sir David Harrel, chairman of Interim Court of Arbitration 1918-19, in connection with industrial disputes. K.C.B.: Sir Richard T. Glazebrook, late Director of the National Physical Laboratory. The new Baronets include: Mr. John Traill Cargill, chairman of the Burmah Oil Company, Limited, and a director of the New Oil Refining Process, Limited; Sir Arthur Trevor Dawson, vice-chairman and a managing director of Vickers, Limited, and a director of W. Beardmore & Company, Limited; Mr. E. M. Edgar, head of the firm of Sperling & Company, merchant bankers, has large interests in the coal, steel, and shipbuilding industries; Sir Erik Olaf Ohlson, Sheriff of Hull, 1913-15, and head of Messrs. Ohlson & Company, coal exporters, Hull; Colonel John Roper Wright, J.P., chairman of Baldwins, Limited, Clym Colliery Company, Limited, Dillwyn & Company, Limited, and other concerns. Knighthoods have been conferred on Mr. F. G. Ogilvie Assistant Controller in Trench Warfare Research Department, Chemical Warfare Department; and Mr. H. M. Robinson, Chief Inspector of Factories.

New England Foundrymen's Association.

At the meeting of the New England Foundrymen's Association, held at the Exchange Club, Boston, December 10, Robert E. Newcomb, president, presided. B. M. Shaw, Walker & Pratt Manufacturing Company, Watertown; Thomas Scott, Brown & Sharpe Manufacturing Company, Providence; and H. E. Wetherbee, James Hunter Machine Company, North Adams, were appointed a nominating committee for the selection of officers to be voted on at the annual meeting, which will be held at Boston, January 14.

Frank B. Gilbreth, Providence, R. I., consulting engineer, then addressed the meeting, his subject being, "What Industry Must Do To Allay Unrest; How It Must Be Done," using as the basis of remedy his 16 elements in the cycle of motion. He started his address by informing the members present that they did not know their own business. He said that the fact that no two foundrymen could get together and agree, to his mind, proved that he was right in saying they did not know their business. "If no two can agree, you can't be all right, and therefore you don't know your business." He then went on to show, with the help of illustrations thrown on a screen, that up to the present generation the world in its various eras of construction failed to leave behind a record of method. The only records left to us, he said, were those concerning results.

From that point he explained his idea of the general scheme of production, motions, element of time, direction, etc., always referring back to the fact that in practice the foundrymen did not know their business. Mr. Gilbreth impressed upon those present that he was dealing in theory as to the elements of the cycle of motion as applied to the foundry business, and his effort was to prove that if his theories were applied to foundry workings the workman would be happier, his pay envelope fatter, and his production greater.

Correspondence.

To the Editor of THE FOUNDRY TRADE JOURNAL.

SIR,—In the January issue of THE FOUNDRY TRADE JOURNAL I am reported as saying, during the discussion on the paper, "Annealing of Castings for Machining" (Lancashire Branch of I.B.F., November, 1919), that "I did not think annealing had the slightest effect chemically upon the casting." My reply was to the Chairman's question whether "the borings had any effect in the way of changing the casting chemically," and was to the effect, "that the cast-iron borings had not the slightest effect chemically upon the casting." This is very different from saying that annealing had no chemical effect on the casting, and I should be pleased if you will correct this error in your next issue.—Yours, etc., HILTON MILLS.

9, Stocks, Middleton, Manchester.

To the Editor of the FOUNDRY TRADE JOURNAL.

SIR,—In your résumé of the Scottish Branch proceedings of the Institution of British Foundrymen of November, 1919, in this month's issue, the lecturer is made to say that a high percentage of ash in coal dust for use in moulds is not an objectionable feature, while he had seen a coal dust used containing 25 per cent. of ash which gave satisfactory results.

Will you allow me to quote from the actual typewritten copy of the lecture as read? After referring to the danger of using a too refractory coal, the Paper proceeds: "On the other hand, there has been tried coal containing as high as 25 per cent. of ash, the result of which can only be to produce a casting with a skin of extremely grey colour and a rough surface." Surely this is quite the contrary of a "satisfactory result."—Yours, etc., THE LECTURER.

January 13, 1920.

THE DEVELOPMENT OF THE INTERNAL-COMBUSTION ENGINE.—Mr. Chas. Baxter, in a paper submitted to the Institute of Marine Engineers, discusses the developments of the internal-combustion engine. The paper is more in the nature of a historical epitome, but he has a few interesting remarks on the general subject of design. A small amount of trouble is still met with in connection with the heat gradient in cylinder walls and pistons, resulting in the occasional cracking of the parts from unequal expansion. Many makers are now constructing engines with desaxé cylinders, i.e., setting the cylinder not directly over the crank-shaft and thus equalising the pressure upon the cylinder walls. Dealing with future developments, the writer is of opinion that the general design of the internal-combustion engine is very unlikely to be radically changed. Supercharging has been tried with some success. Also there is a prospect of development in the petrol-steam system of engine such as has been evolved by Still. The writer also sees developments ahead in the combined steam and gas turbine.

Core-Floor Essentials.*

By A. R. Bartlett.

It is not proposed in this paper to cover all core-making practice, or suggest that it will eliminate all the troubles met with in producing satisfactory cores for every type of work; but by proper study of details it is possible to produce cores that will give a better finished appearance to the castings, instead of the rough surfaces and interiors oft-times seen where cores form part of the mould. There is no reason why the surface of a casting formed by the core should not be as good as the surface formed by the mould proper.

Another bad feature of cores is the indifferent way a large number fit into the place prepared for them and the unsatisfactory system of filing and fitting which is often employed, instead of having correctly made core-boxes. Before the advent of the rotary core machine it was quite common to get instructions not to put round cores in, as it was more satisfactory to drill holes from the solid than try to correct oval or misshapen holes. It is often very difficult to correctly drill a hole on account of the drill following the line of the cored hole; the sand adhering to the sides of the hole spoils the drill.

Action of Metal on Cores.

It would be wise to consider what takes place when the metal comes in contact with the cores. Before pouring, the mould is full of air, but as soon as the metal enters the air becomes heated and expands, thus increasing its volume and creating a pressure in the mould. It naturally follows that the metal in filling the mould must expel the air. Then, also, steam is generated as the metal enters, and this must be expelled. The volume of air and steam escapes through both the mould and the core, thus the need for what are usually termed vents as a means of conducting the air and steam away and allowing the free passage of the metal.

As soon as the metal comes into contact with the mould or core a crust of metal forms almost instantly, which prevents the air from the core or mould passing back into the metal, but if the air passages or vents are not free enough, or the sand mixture is too close, the passage is obstructed and "scales" or stripping off of the walls of mould or core result. Where binders containing an excess of volatile matter are used, larger quantities of gases are generated, and thus it is not advisable to use artificial binders with clay-bonded sands, but only with silica sands, these being more open and more easily vented. The perfect drying of cores eliminates a large amount of volatile matter, but this must not be overdone or the core, of course, will not hold together. Blacking or other refractory material will assist in preventing the metal from cutting or washing the core away.

Sands and Binders.

The sand used in coremaking is usually that which is found in the vicinity of the foundry. This is not always good practice; it may be suitable for some types of cores, but the nature of each type of core and its position in the mould should be taken into consideration, and if better results are obtainable with other sands, such sands should be procured if possible. In these days, when binders are so largely used, it is not desirable to pin faith to any one particular brand, for some are suitable for light castings and useless for heavy ones. Again, it is not always the most advertised or yet the dearest that is the best for any and every job. The sand to be used must be taken into consideration when using binders, for some will mix well with clay and some will not; also some silica sands work better and produce more efficient cores with different binders. The wrong binder oft-times leads to additional expense through the use of excess in an attempt to get the correct bond.

It is not unusual to find stoves installed for core drying that were built for the practice of 50 years ago, and with no possible means of regulating the heat or the amount of fuel used. The stove that is used for drying heavy loam work and silica-sand cores at the same time cannot possibly be called satisfactory, for the heat that is required to dry the loam work will be fatal for the silica-sand core. Although a certain practice may be good in one district on a given type of work, it does not follow that the same will apply in another district, even on the same type of work, owing to the details of the foundry plant and materials not being identical.

Mixing and Binders.

Inefficiently mixed core sand will give weak places in some cores and hard surfaces in others, thus causing breakages in the weak spot and scabbing from the hard surfaces. To ensure a perfect mixture, after having experimented and found the correct quantities of each ingredient, measures should be used so that the operators cannot make any mistake. It is not safe to trust to the method of "one shovelful of this and one barrow of that." The mixture should have definite proportions.

Mechanical means for mixing are undoubtedly the most efficient, but we are not all in the happy position of having the ideal tool for the purpose. Failing a mill or a mixer, there is the old-time method of milling the sand on a plate or bench with a piece of pipe, pushing the heap of sand in small quantities from us and dragging it back in the same way until thoroughly mixed or milled. Or, again, it can be trod and ground under foot till thoroughly mixed. It is not advisable to grind oil-sand mixtures.

Every grain of sand should be coated with the binder, whether oil, clay or other binder is used, to make it adhesive to its neighbour. If no milling is considered necessary, it should be thoroughly rubbed between the hands to mix it. Sifting afterwards in each instance will help to make the mixture perfect. In mixing the ordinary clay-bonded sands a large batch can be manipulated, as it does not lose any of its virtues if not all used up; it only getting dry, which can be remedied by the addition of water and re-mixing. This is not the case with oil-sand mixtures, with which it is advisable to mix only what will be used

* Read before the London and Birmingham, Branches of the Institution of British Foundrymen.

readily, as the oil sinks to the bottom of the heap, and if in contact with a wooden bench, gets lost. Also any loss by evaporation cannot be replaced correctly, as there is no ready means of judging how much is lost.

One finds almost any sand being used for core making, and this indicates that all sands may be useful for given types of cores. Sands may be considered to be of two types, viz., bondless or sharp sands and bonded or clay-mixed sands. The former are used with oil or other binders for cores that are required to vent freely and be easily fettled, and the latter for the heavy type of work, where larger volumes of metal are in contact with them and which have to stand rougher handling. All cores must be porous enough to allow of the escape of gases—must vent freely; and in making up mixture one should take into consideration the ingredients and have the correct proportions of opening compound, according to the closeness of the sand being used. This applies only to the bonded sands, and must not be overdone, for each individual grain of sand must be bound to another, and an exces of any opening compound destroys the bond. Here the thorough mixing helps to avoid trouble.

Also must be considered whether the mixture is to be used for cores for iron, aluminium, brass or bronze. Coarse sands may be used for iron or aluminium, as these metals are not so "searching" as the brasses and bronzes. With the latter it is advisable to use finer sands, on account of the difficulty in fettling cored surfaces where the metal has eaten in. Again, the coarser sands have a greater tendency to crack during drying, and, no matter how blacked or coated, the metal will show where the cracks have been.

Binders are many and various. Founders years ago used to swear by stale beer; this was before the advent of oil, and the beer was used chiefly with clay-bonded sands. Also flour or other meal was used. Though these were sometimes used with silver sand for cores wanting free vents, they had to be handled with care. With the free use of silica sands came many binders, among the best known being core gum, various products from molasses, various oils, the chief being linseed oil, also resin, pitch and glutrin. The amount of binder to be used with any given quantity of sand will vary according to the volume of the core to be made. The smaller and more delicate the core, the more binder, within reason, will be required. The larger the core, the less is the need of binder, on account of its bulk making for strength. But we must always remember that an excess of binder in the delicate core above what is really needed to give it the desired strength will probably choke and retard the vent.

Of all the binders for silica sands, linseed oil has been found by the writer to be the most effective; it drys quicker than most other oils and binders, therefore it is more evenly distributed in the dried core. Other binders have a tendency to run to the bottom of the core, or, in the case of some of the water-soluble binders, to come to the exposed surfaces in the stove through evaporation. Again, oil is very active, and permeates the whole of the core, whereas such binders as flour stay where they happen to be, and if they are not mixed well one gets hard and soft places. Resin melts under heat, therefore the core is often "closer" on the bottom surface, owing to the resin having run there and filled up the interstices between the grains of sand. Molasses, being sugar, boils under heat, and the core gets coated on the top surface with a film which obstructs free venting and causes scabs; therefore such cores should be dried slowly. This illustrates why the one stove will not dry any and every core successfully at the same time.

Two or more binders should not be mixed together, as a rule, though there are exceptions; but we cannot expect an oil to mix effectually with a water-soluble binder. Flour helps to get a successful core from the rotary core machine, in conjunction with oil, but this is an exception, and would not be needful in ordinary core making. The writer used it on account of the silica sand employed being very coarse and not holding together when travelling down the guide plate.

Mixtures and Drying.

No matter what mixture of sand is used for making cores, the desired result will not be attained if correct drying methods are not employed. Practically every mixture wants different treatment in this respect to get perfect results. Large loam cores made of the following mixture—10 parts strong Erith sand, 15 parts old floor sand, 5 parts sawdust, 2½ lbs. of cowhair—were dried in a large stove 26 ft. deep, 16 ft. wide and 16 ft. high. The stove was filled with large cores and loam moulds, and the heat was recorded by a thermometer registering from 100 deg. to 1,000 deg. F. The stove was filled and door pulled down at 7 p.m., remaining closed till 7 a.m., thus giving 12 hours' continuous drying. The fire was fed from the outside, and the heat registered 250 deg. when the door was closed, gradually increasing to 450 deg. at 12 p.m., and being kept at that heat till 4 a.m. by proper stoking. Then no more coke was put on, the heat gradually falling till, at 7 a.m., it registered 300 deg. The fire by then was practically burnt out, the heat generated being held by the walls of the stove. The coke burnt was approximately 15 cwt.

A large core made with a mixture containing 20 parts sea sand, 20 parts inland silica sand, 1 part linseed oil, 1 part water, received the following treatment:—The whole of the sand was thoroughly dried before the mixture was made up to ensure the mixture being always regular in water content. These cores were dried in a stove especially designed for drying this type of work, and attached to it was an auxiliary stove designed to dry the cores after blacking. The heat of the stove when the door was pulled down registered 200 deg. F., the fire being lit one hour before. The door was pulled down at 6 p.m., and remained closed till 7 a.m. One cwt. of coke was used for lighting the fire, then at 7.30 p.m. another cwt. of coke was put on, at 9.30 p.m. another cwt., and at 12 p.m. the fire was clinkered and another cwt. of coke used. The heat was thus kept gradually rising, till at 2 a.m. it registered 350 deg. F., and remained approximately stationary till 4 a.m., when it gradually went down, till at 7 a.m. it registered 250 deg. F. Every core was thoroughly dried, and could then be safely handled for blacking. These cores must be blacked warm, otherwise the blacking will not take kindly to the oil sand. The stove used was furnished with a series of dampers, as also was the auxiliary stove, so that if the heat appeared to be getting too high or too low it could be regulated.

Small cores made with the same mixture as the

previous one, being much more fragile and less in volume, have to be dried in a different stove. The heat in this stove only registers 100 deg. F. when the cores are put in, travelling to 150 deg. F. at midnight, and then allowed to go down, till at 7 a.m. it registers 50 deg. F. No flame is allowed to go into the stove proper, the heat being generated in a combustion chamber and then allowed to enter the stove through the dampers. The quantity of coke used in this stove is half a cwt. after the fire is alight. In this stove small cores, containing a mixture of 1 part old sand and 1 part Mansfield sand, tempered with water, are dried at the same time.

The cores from the rotary core machine are dried in a stove of the same type as the one just mentioned, only the heat is not allowed to get above 120 deg. F., and is kept there for four hours. All the writer's stoves are night-fired, thus avoiding the loss of heat entailed in continually opening and closing doors. The mixture in these cores is 15 parts sea sand, 15 parts inland silica sand, 1 part linseed oil, 1 part flour, and ½ part water. The mixture before being put through the machine appears rather dry, but it will not come through successfully if made too wet; the grinding effect of the conveyor against the die causes the mixture to become more homogeneous, and if too wet gets jammed. It is contended that the shrinkage of the flour and water gives more vent than the appearance of the core would suggest, and that the flour and oil bond burns out at a low temperature; hence the reason for the low heat in the stove and the ease with which these cores can be fettled.

A sand mixture used for heavy cores is as follows:—Sweepings from the loam floor, 12 parts; new sand, 6 parts; sawdust, 4 parts, tempered with water. The whole is ground in a mill and sifted before using. The cores made from this mixture are dried in the same type of stove as the loam cores first mentioned, only placed further away from the fire hole. For steel castings the materials used must be of such a nature that they will not fuse at the high temperature at which steel is poured, yet the cores must be built so that they will readily crush under shrinkage of the metal, and thus avoid trouble through the contraction of the casting.

With grey cast iron and malleable iron of the light type of casting, nothing can compare with silica sand and oil. These cores have the advantage of not absorbing moisture after drying, and can be made in large numbers and kept in stock. They also need very little to support them in the moulds, keeping rigid under the pressure of the metal. We have now some cores made in excess of an order wanted three years ago, and being called for again are using them quite sucessfully.

Cores for brass and bronze having to encounter less heat than those in steel or iron, need not have such a high refractory nature, and must be of necessity closer as already stated. With aluminium, owing to its excessive shrinkage, the core material must readily crush under pressure. The best mixture would be one with a thin, hard skin surface, with a soft interior structure. This can only be obtained by a binder which comes to the surface during drying.

Costs.

Cost with most of us is the one factor which counts; many things must be taken into consideration when approaching this question. Amongst the most important are the following:—

We must consider the strength of the core, both green and dry; for many have to be handled green and broken cores cost money. The surface of the core wants considering, for it forms some face of the casting. The freedom of venting. Will the core resist moisture, and is it necessary for it to do so? Can we get the cores fettled easily? Does the mixture give off fumes that are objectionable and thus stop production? Is the mixture easily handled and procurable? What is the cost of drying the different mixtures? Is it advisable to go in for sand mixtures that involve special core plates? After having answered these questions we know what costs are justifiable. In other words, costs control how we can get the highest number of perfect castings and the lowest number of wasters.

Relative to the first question, the green core may be of considerable height, therefore must be of sufficient strength to support itself during handling and during drying. This can be secured by using a clay bond and by judicious use of core irons. The strength of the dry core must be governed by the amount of pressure it has to stand when the metal is poured. The second question presents the need of considering what coating of blacking the core will take to give a clean surface. The third query of venting makes us consider what size of sand grains is desirable, also what binder we should use, or what opening compound is wanted. Again, the metal the castings are made of has a great bearing on this point. Iron castings, for instance, having a very small print area, would need a maximum amount of vent to be allowed for in the mixture, while with aluminium only, the minimum of vent for the escape of gases would have to be taken into consideration. Then, as to whether the core has to resist moisture will depend on how long it will be in stock before using, and for how long it will remain in the mould before pouring; also whether it is to be used in a green-sand mould or in dry sand.

The following is an instance where the value of oil-sand mixtures comes in. We had some moulds cored up, and through unforseen circumstances could not cast them for four days, and although they were in green-sand moulds, we were able to cast them without doing anything whatever to them, the result being entirely satisfactory, none blowing or breaking through having got damp.

The next question, ease of fettling, appeals readily to every foundryman, for the core that leaves a casting readily and gives a clean surface eliminates a lot of cost, trouble, and delay. The chief cause of trouble in this direction is an excess of clay in the mixture, which becomes extremely hard when in contact with heat. The reason that the disagreeable odours given off from some core mixtures affect costs, is simply because the men have to knock off work on account of the unpleasantness, to get a breath of fresh air, thus ceasing to be producers for the time being. The quantity of cores that can be produced from any given corebox will be either increased or decreased according as to whether the mixture is the best for handling and turning the cores out successfully. A mixture with an excess of a sticky binder will not readily leave the corebox, and thus one must study what is the correct amount of binder, consistent with getting absolute necessary strength for handling the dry core. Here again is where the cost of drying comes in. A mixture that has an excess of binder

needs more drying than the one having just the amount needful, thus increasing the fuel bill, also the space and time taken up for drying.

The question of special tackle for turning cores out of the corebox oft-times makes the use of some binders prohibitive, unless a large number of the one particular core is needed or there is the possibility of repeat orders. This applies particularly to oil-sand mixtures and all binders used exclusively with silica sands. The usual way to overcome this difficulty, where it is essential to use such mixtures, is to make the cores in sections having flat surfaces, so that they can be turned out on the flat surface and then pasted together when dry.

Stoves.

Many cores are ruined during the drying—or, to use the better term, "baking"—through judgment not being used as to where to place the cores in the stove. A little thought will convince the operator that the heavy or large cores should be placed where the greatest heat is known to be, and the lighter core farthest from the heat; thus, if shelves are in the stove, the highest ones get more heat than the lower ones (this only applies to the usual foundry stove, that has no special features). Again, the area nearest the fire, or the combustion chamber, will be the place to put the largest cores. Where unskilled labour is employed for loading cores into the stove, unless keen supervision is exercised, the loss from this practice is very serious, especially with delicate oil-sand cores, for it is both costly and agravating to have cores fall to pieces through being burnt. This is where the trained firemen is valuable, also where the use of the thermometer avoids loss and rapidly pays for itself. The fireman should be instructed to keep a record of the heat registered, and after a little experience will know just what the amount of heat required will be, and the minimum amount of coke will therefore be used to get the desired result. The core that is dried correctly will give the best results and thus avoid wasters and the blaming of the coremaker or moulder for faults that cannot be truthfully laid to their charge.

Of course, the core stove must be designed correctly. The not uncommon method of having a fire-hole placed in the floor of the stove is not conducive to perfect results, for the heat around the fire-hole is much greater than in any other part of the stove. Therefore the cores nearest get burnt and those farthest away do not get dry. Instead of letting the flame go direct into the stove, it is desirable to design the stove with a combustion chamber sufficient distance from the actual drying ground to allow the products of combustion to enter the stove at a uniform temperature. We have a stove especially designed in this manner for drying large quantities of oil-sand cores. The fire is charged from outside the stove, the flame travelling over a bridge in the same manner as in an air furnace, into a combustion chamber which is fitted with dampers which control the amount of heat entering the stove, thus ensuring perfect drying without risk of burning the cores.

The writer has seen moulding boxes and core wagons and metal parts of a stove, that have been badly distorted and even melted, through excessive heat coming into contact with them. This should never happen, for no core requires the amount of heat to dry it that would distort or melt cast iron. Therefore if any metal get distorted in the stove, it is positive evidence that the heat has been too high, and that fuel has been wasted; also that cores in the near region of the fire have been spoilt and costs have gone up.

While dealing with core stoves, it may be as well to give a thought as to the best means of getting heavy cores into the stove. This is usually done by loading them on a core wagon and pushing or pulling the loaded wagon into the stove. But the very poor wagons met with in some foundries, and the means whereby they are got into the stove, would not do credit even to Tubal Cain in the days when the earth was young. The writer has seen in a large foundry in the North of England core wagons made entirely of cast iron by the foundryman, being pinched along by very indifferent crowbars, on plates that were put down under the wheels, wherever it happened to be going. The resultant irritation to everyone concerned can be better imagined than described.

Where heavy work has to be handled it pays to put down a good railroad on a concrete foundation, one that will practically last for ever, and have a strong steel core wagon with steel axles and substantial wheels. The track gauge should be as broad a gauge as practicable to avoid the possibility of getting the wagon loaded out of balance, and the load should be evenly distributed, the wagons being pulled in and out of the stove by mechanical means. Simple means of lubricating should be provided. Oil and grease are not the best things for this purpose, for they bake hard, and though they may help to get the wagon in the stove, the pulling out again is made hard through the oil or grease caking hard and jamming the axles in the bearings. A good lubricant is plumbago and water, put on in the form of a paste. This is only possible where the axle runs under the bearings. We had a core wagon designed with roller bearings, but it was an absolute failure, the steam generated when the cores were drying getting into the bearing and causing rusting and consequent jamming. The only means of lubricating was by oiling, and this added to the trouble.

Machines.

Machines for core making are not so universally in use as machines for moulding, but there is no reason why they should not be more used than they are. We see jar-ramming machines, ramming and turning over all types of moulds, which, when studied closely prove that core making by the same means is quite practicable. The moulding box can be taken to represent the core box. We have ten jar-ramming machines that were sold as moulding machines, doing nothing else but ramming cores, and we find that the cores are more evenly rammed, consequently they vent more readily than a hand-rammed core, and they have not the hard and soft places that a hand-rammed core has. Another reason for their use is that the core is rammed quicker. Although the jar-ramming machine lends itself readily to ramming of cores, there is no reason why the older type of machine, known as the hand-rammed moulding machine, should not be used for the purpose. One well-known foundry is continually using what was a press-head machine, with a turnover table. The press head was removed and the ramming done by hand; the core box, when rammed, was covered by a plate and clamped, and the whole turned over. The core box being attached to the turnover table, was drawn off the core, a vibrator being used for loosening. By this means the life of the core

box was lengthened, and a perfect draw ensured. Similar work I have also seen done on a roll-over moulding machine.

The type of machine, known as the rotary core machine, or "sausage" machine, most of us are conversant with. It is fitted with a series of dies and screw conveyors of various sizes, ranging from ⅜ in. to 7 in. Cores can be successfully turned out from this machine, either round, square, rectangular, or any shape in straight lengths of 2 ft. The sand is fed from a hopper from which it falls on to the screw conveyor, being then carried forward through the die on to corrugated plates, down which the core travels, and when arriving at the end, the core is cut off with a knife close to the die, the plate being then moved to the next corrugation and the process repeated. According to the mixture being used, it is sometimes advisable to place the plate on an incline, so that the cores run down hill, otherwise the pushing along the plate causes the core to crush and only short lengths can be got out.

Another machine used for making straight cores is known as the plunger machine. Personally, I have no knowledge of it. I believe it is fed from a hopper the same as the rotary machine, and the sand is forced through a die by a plunger worked with a cam action, the plunger being brought back to its original position by a spring.

Sand Storage.

All core sands should be kept under cover, and not be dumped down in the yard. Sand that has an excessive amount of water in it costs money to dry. Also in the winter frozen sand gives endless trouble. The storage bins should be placed in near proximity to the core floor, there is no reason why one should pay money for carrying the sand long distances, if the storage is planned correctly. The same applies to all other materials to be used.

For the storage of large quantities of sand, concrete bins are undoubtedly the best. There is no fear of rotting taking place as would be the case if made of wood. Even if wood is used for the sides or divisions between bins, the floor should be composed of concrete, thus giving a hard bottom for the shovel to work on. In the case of sand being dumped on the ground, it will often happen that some of it will get mixed with the sand, probably causing weakness in the finished core or scabs on the castings.

Core Setting and Core Gauging.

Core setting and core gauging are important matters in all foundries. The interior diameter of a jacket core, or any core where it can be applied, should be tested with a star gauge, the external diameter being checked by a caliper gauge. This method is only practical where there is a run of any one given size of core. This is a much more satisfactory method of measuring the diameters or sizes than with the ordinary calipers, as there is no fear of movement. For the testing of prints, as the core is required to fit into its place when placed in the moulder's hands, a ring gauge should be made to size, no matter whether the core is perfectly round, elliptical, square, or rectangular, and then one can avoid fins and the possibility of the core shifting through being small; or if it is large crushing would result. Of course, this would only be worth while if there is a large quantity off a given job. All jigs of a small size should undoubtably be made of metal, for the sake of continual accuracy, and to ensure a long life. There is no reason why core jigs should be confined to small work; a wooden, or if justified, a metal frame having the bearing or print parts of the core accurately placed relative to each other, is valuable in the larger work, as the core can be lowered into it before leaving the core floor, proving its shape and dimensions, and thus avoiding lost time in assembling in the finished mould. We are accustomed to making many intricate castings with complicated internal structures. When jigging the cores for such, we always do so from a machined surface plate, thus always having a true bed to start from and to measure the varying heights of the different cores and machined surfaces. On this same plate the cores are assembled with the aid of jigs, and are, of course, corrected if at fault, before being placed in the hands of the men who will assemble and close the mould.

A scribing block is another tool used on the surface plate to ensure any given surface that is away from the edge of the core being accessible. It will readily be seen that by such a process of jigging and gauging what the ultimate advantages will be when several cores are to be fitted into one another. Assuming cores of this description were sent straight from the coremaker to the moulder and put into the mould without gauging, the possibilities are that the ultimate height of the last core placed in position would be such that the top part of the mould would not go into place, or if forced would break the core or else the mould; or if on the small side unequal thickness of metal would be given with a possible movement of some core, and the metal getting into the vent with fatal results. It is also possible to use setting jigs for placing cores correctly in the mould to insure the proper fit of the various parts. Accurate length to the cores is guaranteed by a movable check, which is fixed at any desired length by means of a thumb-screw.

Cores should not be handled more often than is really needful. It costs money, and every time a core is handled there is risk of damage. Cores should pass straight from the coremaker to the oven, and from the oven to the moulder or the jigging table; or if made for stock to properly arranged storage. This should be, if possible, over or at the side of the stove, or, at any rate, away from steam or damp-ladened air. Cores should never be left laying about on the moulding floor, for they will absorb the steam or moisture from the floor sand, especially when it is being watered and mixed.

Discussion at Birmingham Branch.

THE BRANCH PRESIDENT (Mr. H. L. Reason) said that, with reference to core ovens and the temperatures for drying cores, Mr. Bartlett had pointed out the slovenly way in which they went about these things, sometimes even with the result of melting the boxes which held the cores. He thought everyone would appreciate the importance of having some method of estimating the temperatures in the stoves so as to avoid overdrying and underdrying. He would like to ask in what part of the core oven the thermometer was fixed, as it was well known there was a considerable difference of temperature in different parts of the core stove.

MR. F. HOLBERRY said he was quite taken up with the construction of the stoves as described by Mr. Bartlett, and especially with the combustion chambers. If they could eliminate the flame

altogether from their drying stoves they would get more regular heating and a more satisfactory drying of the cores. He himself had had very little experience outside clay-bonded sand, as his work lay practically all in the heavy line. He did not know whether Mr. Bartlett could inform them whether or not oil-sand would be of much advantage in that line. If oil-sands could be used for heavy work, what particular composition would Mr. Bartlett recommend? He had used oil-sand for smaller work, but had never tried it for a very heavy section.

Mr. D. Dalrymple said he was more particularly interested in small intricate cores with projections, which must be very accurate to size, and his trouble was with the contraction caused by oil binders and also by baking, which altered the size in some cases considerably. He worked to about 160 deg. with gas-fired ovens.

Mr. F. J. Cook said that the paper was very interesting, but he did not agree with some of the statements. He did not mean that Mr. Bartlett was wrong, but that the way described was not the only way. Mr. Bartlett had done good service in pointing out the importance of greater care in the selection and mixing of sands and also in drying. With regard to oil-sands and oil binders, a very important point was getting the oil and water properly mixed. He did not think that the author had laid sufficient emphasis on that. It was essential to have a definite mixture throughout the core in order to obtain good results. It had been his practice for many years to dry the sand thoroughly before mixing. One then knew exactly the amount of moisture in the mixture. The mixing of the oil with the water was a difficult matter. As was well known, oil and water did not readily mix, and if this matter were not attended to one might get oil in one part of the sand and water in another. A short time ago he adopted a machine by which the oil could be easily emulsified in water. In this way he got an emulsion which gave a uniform mixture throughout the sand. Before he adopted that method he had many difficulties, especially with sharp sands. There were some things which Mr. Bartlett had mentioned which were not in accordance with his (Mr. Cook's) practice, although they might be equally right. For instance, he had found it far better to mix overnight for use next morning. He found that if the sand were left for a time after mixing the mixture was much more thorough than if the sand were used immediately after mixing. Mr. Bartlett had rightly pointed out that the oil-sand must not be left lying upon wood or anything likely to absorb the oil or the water. His own practice was to leave it on plates. He agreed that one should never grind a sharp sand for oil-sand work because it was important to preserve the sharp corners. He also agreed as to linseed oil being the best binder. But one had to pay the price for it. As to the drying of cores, a great deal depended upon how far in one wanted to dry the core. Of course, in many instances it would be dangerous to dry the core right through. He remembered having a core of thirty pounds weight which had to go into a cylinder section which was very thin, and if that core were dried to a depth of more than an inch or two the casting would crack before the core could be got out. In large works he had seen hard-baked cores which would take more time to get out than it would take to bore out the solid metal. Very often cores were spoiled by using too good a sand. There were many classes of work in which the sand should be as large as could possibly be used. He did not quite agree with the author as to roller bearings for core wagons. Mr. Bartlett said that these were no good, but he could show Mr. Bartlett wagons carrying 35- or 40-ton cores in which roller bearings answered admirably. His practice was to bore out the opening larger than the spindle and line it with silver steel. The bearing was not filled in the way in which one ordinarily filled roller bearings; the number of rollers put in was one less than was required to fill the space. No difficulty had been found in using such bearings for heavy work.

Mr. H. Pemberton was quite in agreement with Mr. Bartlett as to linseed oil being the best binder for an oil-sand core. As a rule, foundrymen fought shy of oil-sand for large core work, though it had been used to some extent for large work in the North of England and also in the South. Generally speaking, foundrymen were very chary of departing from the old green sand or loam sand. At Derby they used oil-sand cores for very nearly all their work in the brass foundry, but in the iron foundry they used it only to a very small degree. He did not notice that Mr. Bartlett had given them a mixture for cores for lead bronze casting. Lead bronze, or very heavy brass, as some of them were aware, had, as Mr. Bartlett told them, a very penetrating effect upon the sand in the mould and cores, although it was cast at a very low temperature. That, he assumed, was owing to the very long time the metal remained liquid in the mould as compared with iron or steel. He had in mind a pump which they made, and in casting which a core had to be used which was round. They found that the metal ate into the sand to a very considerable degree. The core would probably have 2 in. of metal round it, and they found that the action of the metal on the sand had a very detrimental effect when it came to fettling the casting. He was wondering whether an oil–sand core would stand in that sort of work. They had tried a loam coating, but they still got the metal penetrating into the core.

Mr. J. Willmore asked whether Mr. Bartlett had any suggestions to make with regard to the saving of oil. For instance, had he used glutrin? In the foundry where the speaker worked they made hundreds of this class of core each day, and it was found that by using glutrin they saved half of the oil used formerly. He agreed that it was best not to mix more sand than would be required, say, from breakfast till dinner-time, and the same in the afternoon. He had not found it work so well when it had been mixed overnight. A mixture that he had found very serviceable for the majority of his own cores was one shovel of sea sand, one of red Stourbridge sand, one can lidful of oil, and one lidful of glutrin and water (the lid of an ordinary quart breakfast can). As to oil-sand cores for brass, did Mr. Bartlett mix such a core with oil and water. (Mr. Bartlett: "Yes.")

Mr. J. G. Dobson said that reference had been made to the kind of stoves used in the North, and fired through a hole in the wall. He had not yet found anything in the new fancy stoves to beat the stoves used in the North of England. What was wanted was a stove in which the fire was in the floor, the ash hole and door to feed it outside, and the flues on the floor at the sides of the chimney outlet; so that the heat rose to the top and forced

the cold air and moisture from the wet moulds outside. A door should be put on the ash hole as well as the fire door, to close when the stove was heated as required.

MR. WILLMORE: Mostly our stoves are gas-fired.

MR. HOLLOWAY commented upon the remark of Mr. Bartlett as to grinding, and said that he would like some further explanation of that. He would like to know what oil-sand Mr. Bartlett recommended for motor cylinders.

MR. BARTLETT, replying on the discussion, referred first to Mr. Holloway's question as to core sands for motor cylinders. He said that he had never made any motor cylinders, but he had on the table a little casting which Mr. Holloway might think resembled a motor cylinder as far as the core was concerned, and that core for that had been made in oil-sand. With regard to stoves, he did not speak detrimentally of the stoves in the North of England in a general way; he only spoke of the exceptions. Mr. Dobson had spoken of having a fire kettle or devil in the bottom of the stove. He (Mr. Bartlett) did not think that was a good thing. He did not think they could get good results with a square hole in the wall and a hole in the bottom. It was true that by admitting the fire into the stove loss of heat was avoided, but there was always a possibility of spoiling something in near proximity to that fire. When drying cores in large quantity in such a stove some cores would be too near the fire, and would get so burnt that in the morning they would fall down whilst others would not be dried. This meant that coke would have been burnt in waste. Dealing with what he conceived to be Mr. Dobson's idea of a properly-arranged flue, Mr. Bartlett made a sketch upon the blackboard, and said that Mr. Dobson spoke of a flue about 3 ft. square. This, however, would take up valuable drying space. But assuming that the full load could be got into the stove, the heat would be so unequally distributed that the moulding boxes and core plates would probably be distorted at one end and the cores would be similarly affected, so that the result would be a distorted casting and a great deal of machining to correct the error, which cost money, would be necessary. What they wanted was a stove in which they could get the full benefit of all the fuel. A fierce heat was not wanted. It was much better to have a firehole outside if that was possible, and have a combustion chamber arranged on similar lines to an air furnace, from which the products of combustion would be regulated by means of properly arranged dampers.

MR. DOBSON said that Mr. Bartlett had not properly described what he meant. The flue was on the floor, and the openings were so arranged that nothing but heat reached the cores. In such a stove he had always got his cores thoroughly good.

MR. BARTLETT said that he followed this, but there must be a local heat, and that was not good. The heat should always be attracted from wherever the firehole was to the farther part of the stove, and therefore there must be some kind of damper where the heat was required.

MR. DOBSON: Not a damper.

MR. BARTLETT: Well, a draught-hole, practically a shaft. A great many stoves, Mr. Bartlett continued, were designed with a flue underground, or rather covered up with plates, the flue leading ultimately to a shaft. That was the way the stoves he used were designed as far as the attraction of heat was concerned. With regard to oil-fired stoves, the stove he had described in his paper was used during the war, when they had to make large quantities of oil-sand cores. The oven was arranged for this purpose with movable shelves, and the dampers were arranged, as shown in his illustration, at the bottom. The cores were dried on the shelves, but large quantities of fairly large cores could not be dried successfully in a stove with a hole in the bottom. There would have to be some form of combustion chamber to avoid having a fierce heat in any part of the stove.

Mr. Bartlett sketched an arrangement for a stove fired from outside with relatively a very small fire, and with a series of dampers which could be manipulated from the outside of the combustion chamber. The heat, he said, should be brought to wherever it was wanted without any fierce flame being allowed to enter the stove; the blacked cores did not get the same volume of heat as the green oil-sand cores. It was absolutely necessary that no flame should reach the oil-sand cores.

With regard to glutrin, he had used it as a binder in the proportion of one to ten. When they were going to use it they always dried the sand thoroughly first. Of course, cores so made were not so strong as those made with oil. It was used with a sharp silica sand, and principally for small cores. Glutrin did not bind so well with a sharp silica sand as oil did. Another thing to bear in mind in using glutrin with a sharp sand was that being made from molasses it boiled under heat, and thus one got the core harder on the top surface than in the heart. Of course, any such mixture required to be very well dried.

Mr. Bartlett, referring to Mr. Pemberton's question as to lead bronze or heavy brass, said that oil sand would stand in brass if the right quantity of oil was used, and the right grade of sand, but for brass work a smaller quantity of oil should be used than when the casting was to be of iron. A smaller quantity of oil, and probably a larger quantity of water, should be used. He had used anseline, a French oil, in cores for casting with bronze-au-plumb. It was used in making bearings for turbines. A gallon of water was used with 10 gallons of sea sand and 1 quart of oil. This sand was very fine indeed, although it was called a sea sand, it was more or less a river sand, but because it came from Shoeburyness and contained a certain proportion of Thames mud. He agreed with Mr. Cook that the sand should always be dried in the stove before mixing, because otherwise one could not ensure the core mixtures being always identical on account of the water content. As to mixing overnight and leaving the mixture till next morning, his own experience was that oil-sand when left like that caked together and required to be re-mixed. The practice of making an emulsion of oil and water was quite good if one had the time to do it. He got over the trouble by putting the oil into the sand first and then the water; they always mixed the oil in first and then put in sufficient water to temper the mixture. The suitability of oil-sand for small cores depended upon the size of the core and the making of the binders, and also upon the temperature at which the cores were dried. If the cores were dried at too low a temperature they would be rotten on account of the binder sinking to the bottom, and if there was an excess of binder, and the core was dried at a high temperature, the core would be very hard indeed, and this would affect the casting under constraction if the casting was of a very light type. With regard to oil-sand cores for castings of very heavy section, he thought that they were not really use-

ful. There might be exceptions, but personally he did not recommend making very heavy castings with oil-sand cores except in something complicated, such as a D cylinder head. He often thought that he would like to try an oil-sand core in such a case, but it was rather a dangerous thing. He thought that what was really wanted for big, heavy work was the right sand, which should be probably a very open sand. He believed they had a suitable sand in that district at Stourbridge, this being coarser than the Mansfield sand.

Use of Steel in Cupola Mixtures.

"The Iron Age" publishes a brief note on this subject, abstracted from an article by W. J. Mulcahy in the "Metal Trades":—

Steel should always be melted in the cupola, as any appreciable amount added to the ladle will have a tendency to chill the iron to such an extent that poor results will follow. Steel scrap should not be of too heavy a section, as steel has a higher melting point than cast iron.

The amount of steel that can be used with the best results will depend on the thickness of metal to be cast and the other materials that are to be used. On light sections and with low silicon pig, much less steel should be used than when the castings to be made are of heavier sections and higher silicon pig is being melted. From this statement it must not be construed that the silicon content is the only element to be taken into consideration when making semi-steel. In some cases 5 or 10 per cent. steel will have the desired effect, while in other cases 25 or 30 per cent. would be more desirable.

Generally speaking, 25 per cent. is about the maximum amount used with the best general results. I have on several occasions used as high as 40 per cent., although it was not through choice, but because it was necessary with the material on hand. The great danger from large proportions of steel is sluggish iron and abnormal shrinkage. For the best results, steel should be melted with a low blast, and in a cupola that has a large tuyere area as compared to the area of the cupola.

Steel adds strength to cast iron principally because it reduces the silicon content, reduces the phosphorus, and reduces the total carbon. It will therefore produce a metal lower in graphitic carbon and higher in combined carbon. Of course, the percentage of combined carbon will depend upon the section of metal, the pouring temperature, and the other elements. When figuring a mixture, it is safe to assume that no silicon is present in the steel scrap, providing a rolled steel is used. All rolled steel has a small amount of silicon, but after the oxidation has taken place in the cupola so little is left that it will have no bearing on the finished result. If cast steel is used, the estimated figure to be considered should be 0.30 per cent. silicon. A fair average analysis to be used for estimating purposes would be as follows:—

Rolled Steel.	Per Cent.	*Cast Steel.*	Per Cent.
Silicon	0.00	Silicon	0.30
Manganese	0.50	Manganese	0.50
Phosphorus	0.04	Phosphorus	0.05
Sulphur	0.05	Sulphur	0.05
Carbon	0.20	Carbon	0.25

Steel has some decided benefits in certain classes of work, principally in producing castings that have to stand a test, and where a metal of great strength is desired. Where cast iron is being produced that must have exceptionally good machining qualities steel has no place in the mixtures.

The Cutting Properties of Stainless Steel.

Dr. W. H. Hatfield, of the Brown-Firth Research Laboratories, lectured on December 17 before the Sheffield Cutlery Trades Technical Society on the subject "Cutlery: Stainless and Otherwise, from the Scientific Point of View." He mentioned that he was asked by his directors to ascertain whether the complaints that stainless cutlery would not cut properly were justified, and if so to try to find a remedy. He came to the conclusion that a quantitative hardness test would probably give information of value, and he therefore went to work with the Brinell method of testing the hardness of various knives. The result showed wide differences between the hardness numbers of good and bad cutting knives. For instance, the number of the most satisfactory stainless table blades varied from 500 to 550, while the range of the bad cutting specimens was only from 360 to 400. Similar variations were disclosed in the tests of blades made from ordinary steel. The investigation convinced him that hardness, as shown under the Brinell test, was a direct indication of the capacity of a knife to become a good cutting instrument once it had been properly ground and sharpened, and he commended its use because it would pay cutlery manufacturers handsomely to possess the means of periodically checking in a quantitative manner the effectiveness of hardening and tempering operations.

Tables were given illustrating the important changes which the structure of steel undergoes with increasing temperatures, and the fact was elicited by the investigations that the hardening temperature of cutlery made from stainless steel required to be between 950 and 1,000 deg. C. He advocated the quenching of the heated-up blades of all knives in water and advised that a perfectly hardened blade should always be obtained before proceeding with the tempering, as stainless steel hardens when cooled in the air from a high temperature. Before flying out cold the rough blades should be suitably annealed at from 750 to 760 deg. C., but to fly out cold, in his opinion, represented the best practice. If the blades were not annealed they must be made to fly out at a dull red. Heating to that temperature would do much to soften the blades. He warned the operatives aginst excessive scaling when the steel was exposed to high temperatures, as the presence of scale presented a difficulty in grinding a perfect surface, and any particles left in the final blade were liable to form a seat of corrosion and develop a pronounced defect. Blades should not be ground in such a way that they became heated, or there would be discoloration indicating a condition of the blade in which it would not perfectly resist staining influences. For putting the name and identification marks upon blades the etching process was recommended, as stamping resulted in scale being pushed into the letters in such a way that it could not be removed, and instances were on record where the scale so introduced had formed the seat of corrosion.

The lecturer's conclusions from his investigations were that the cutting properties of cutlery were largely determined by the success with which the exact hardness required was attained; that the requisite hardness for perfect cutting properties could be obtained in stainless blades of all kinds; that stainless steel should be hardened from temperatures of from 900 to 1,100 deg. C.; that hardening should be effective in the first place, and that tempering should be done in the oil bath at 180 deg C.

After being shut down for practically six months through the unfortunate withdrawal of the labour of the skilled tradesmen, the works of the Ebbw Vale Steel, Iron & Coal Company, Limited, resumed operations last week. It is gratifying to learn that a good start has been made in all departments.

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Forthcoming Events.

FEBRUARY 9.

Society of Engineers:—Presidential Address by Burnard Geen.

FEBRUARY 10.

Sheffield Association of Metallurgists and Metallurgical Chemists:—"Steelmaking in India," by A. McWilliam.

FEBRUARY 13.

Manchester Association of Engineers:—Anniversary Dinner.

FEBRUARY 14.

Midland Counties Institution of Engineers.

FEBRUARY 18.

Royal Society of Arts:—"English Canals and Inland Waterways," by S. Preston.

NOTES AND COMMENTS.

Oxygen in Cast Iron.

Under the title of "A Metallurgical Paradox," the question of the influence of oxygen on the properties of cast iron was again revived in a short article appearing in the "American Foundry." The "American Foundry" point out the existence of two schools of thought with regard to this question, one of which considers the influence of oxygen to be decidedly beneficial and the other to be decidedly not beneficial. This state of affairs constitutes the "Metallurgical Paradox."

We ourselves have always been under the impression that "over there" the belief in the beneficial effects of oxygen was predominant. J. E. Johnson, jun., was possibly the strongest supporter, and we also think the author of the theory that to oxygen must be ascribed the increased physical properties of certain classes of irons. In British Patent No. 24,297 of 1913 he states that, contrary to the usual belief, he finds that the desirable qualities possessed by charcoal irons in their qualities of strength, density of grain, and chilling properties are due to the presence of oxygen, and, further, that the difference in properties of charcoal-smelted as opposed to coke-smelted irons are due to the difference in the oxygen content. Incidentally, this patent is granted for a method of introducing oxygen into molten coke-smelted iron, and thereby rendering it more or less the equivalent of charcoal-smelted iron. In spite of the definite conclusions arrived at by this investigator, the evidence for the beneficial effect of oxygen is by no means complete. In a discussion before the American Institute of Mining Engineers, which was abstracted in our columns at the time, Mr. Johnson presented the results of some of his experiments on the influence of oxygen in modifying the physical properties of grey cast iron. Apart from such considerations as the extreme difficulty of estimating small quantities of oxygen present with reliable accuracy, and such experimental difficulties which are likely to arise in the accurate comparison of the chilling properties of grey irons, an inspection of the analytical results leaves one very unconvinced that the difference in the physical test results are due to the small quantities of oxygen present. It appears to us far more likely that the difference in properties can be ascribed to the difference in the condition of the carbon, and Johnson gives no conclusive proof that this is brought about by the presence of oxygen.

Considerably more evidence still remains to be put forward before any definite statement as to the influence of such small quantities of oxygen can be substantiated.

In the short article apearing in the "Foundry," it was further pointed out that certain metallurgists hold the opinion that the properties of the so-called semi-steel mixtures are due to the absorption of oxygen in some form or other during melting, and also that the solution of the whole question of its influence would appear to turn about the correct determination of its mode of existence, and the possibility of its separate identification under the microscope.

In connection with the first point, we should have thought that the absorption of oxygen was not needed to explain the higher physical properties usually obtained by the addition of steel to foundry mixtures. In connection with the second point, it is quite correct that we are still unaware of the mode of existence of oxygen in cast iron, and, as far as experiments in this connection go, oxygen is only found in the gases liberated on heating solid cast iron in a vacuum exists in combination as carbon dioxide, and possibly carbon monoxide. The gases occluded in cast iron have been found by several investigators, for example, Troost and Hautefeuille, Carpenter and Rugan, Herwig, to consist almost wholly of hydrogen and nitrogen,

roughly in the proportions of seven of the former to one of the latter. This does not exclude the possibility of oxygen existing in the form of iron oxide or some other metallic oxide, either dissolved or retained in the solid matrix. Any slag inclusions in cast iron would, of course, contain iron oxides, and beyond this no other form of oxide inclusion has been identified under the microscope.

With regard to the influence of the small quantities of oxygen alleged to be present in cast iron, we ourselves have always taken the view which, although unsupported by any evidence, is worthy of consideration. This view is that the explanation of the higher physical properties in the higher oxygen content irons is due not to the actual presence of the oxygen, but rather to the fact that some change, such as a reduction in the total carbon contents, accompanied by an alteration in the ratio of combined to free carbon resulting from the fact that the iron has been exposed to some conditions of which the presence of oxygen is an index. The conditions may, for example, be oxidising influences, or extremely high temperatures during re-melting. A view of this nature might possibly allow of an explanation of the seeming metallurgical paradox in that the cast iron may be submitted to subsequent conditions, which might, for example, effect a re-carburisation or altered temperature conditions on re-melting without affecting the oxygen content.

THE EDITOR.

Institute of Cost and Works Accountants, Ltd.

Foundrymen in general will be interested in the new Institute of Cost and Works Accountants Ltd., which has been formed recently, and to which reference was made in our issue of November last. The object of this Institute, as set forth by Mr. C. E. Lewton at the inaugural meeting, held in December last, is to promote the higher efficiency of those engaged as cost and works accountants. It is the intention of the Institute to hold periodical examinations and issue certificates of competency, and it is also hoped to establish branches equipped as lecture rooms, and including libraries containing works of reference on the subjects with which cost accountants find it necessary to be familiar.

A series of lectures have been arranged, of which the following have already been delivered:—Mr. Henry W. Allingham, December 17, and Mr. J. M. Fells, on the "Inter-dependence of Costing and Economics," January 14. Further lectures have been arranged, of which full particulars can be had on application to the Secretary, Donington House, Norfolk Street, Strand, London, W.C.2.

We, along with foundrymen in general, certainly wish this new Institute every success, and we would take this opportunity of commending to its serious attention the intricate problems arising in foundry costing.

THE EDITOR.

THE IRON AND STEEL INSTITUTE. — The annual meeting of the Iron and Steel Institute will take place on May 6 and 7 at the Institution of Civil Engineers, Great George Street, London, when the retiring President, Mr. Eugene Schneider, will induct into the chair Dr. J. E. Stead, F.R.S., the new President-Elect. The annual dinner will be held on Thursday evening (May 6) at the Connaught Rooms, Great Queen Street, London. Particulars will be circulated later. By the invitation of the retiring President, arrangements are in progress for holding the autumn meeting in France, next September, provided no unforeseen contingency occurs. Early notice will be given of the precise date and place of meeting, and the localities to be visited. It is regretted that it will not be possible to include ladies in the invitation on this occasion, except in so far as they are members of the Institute.

How to Relieve "Brass Itch."

The symptoms of brass poisoning and the treatment which should be given are described in the current issue of "Modern Medicine," Chicago, Illinois, by Dr. R. P. Albaugh, formerly Director of the Division of Industrial Hygiene, Ohio State Department of Health

The symptoms are evident for several hours after exposure to the fumes which are contained in the whitish smoke and sublimation products from molten brass and zinc. The symptoms start with a dry, parched throat, an irritating and unproductive cough, a feeling of constriction in the chest, lassitude, and anorexia, often followed by nausea and vomiting; a headache sometimes develops, and chilly sensations are noticeable within one to four hours.

The chills rapidly verge into a distinct rigor, which lasts from one and one-half to two or three hours. The application of warm clothing or external heat seems not to diminish the rigor of a chill. Muscular cramps and sharp pains in the joints usually accompany the chill.

The symptoms end rather abruptly, almost by crisis and are followed at once by a profuse perspiration. The patient will probably fall into a deep sleep following the stage of relaxation and without any apparent ill effects.

Brass poisoning does not occur from handling of the metal or the zinc alloys which go into its composition, but is limited to those exposed to the inhalation of the whitish smoke and sublimation products from the molten metal.

There is no specific treatment for brass poisoning, "brass itch," and "brass chills." Zinc is supposed to be responsible for the bad effects. The affection was formerly confused with malaria.

Some workmen find relief in drinking hot milk to which pepper is added. A good purge also seems beneficial. Dr. Albaugh advises the prevention of brass poisoning by better hygienic arrangements in foundries and smelters, elimination of careless habits of workmen, and large, roomy quarters.

We are in receipt of the first annual report of the Industrial Welfare Society, for year ended June 30, 1919. The report calls attention to the fact that the society exists for the purpose of focussing and developing the many activities, industrial, educational and recreational, indicated by the word "Welfare." It was formed originally for the purpose of dealing with industrial boys, but recently its scope has been enlarged in order to embrace all industrial workers. The object of the society is to retain for industry itself the responsibility for, and the direction of, industrial welfare work, and can assist employers of labour:—(1) By discussing with them schemes of welfare work applicable to their own particular works and circumstances; (2) by training and recommending suitable persons for positions as Welfare Supervisors; (3) by supplying Welfare Supervisors with information regarding various phases of Welfare work. Membership consists of employers of labour, and other interested persons, and the minimum annual subscription is five guineas.

Index, 1919.

With the March issue of the FOUNDRY TRADES JOURNAL will be included the index for year 1919.

Erratum.—We desire to call the attention of our readers to an error which was inadvertently overlooked in the January issue of the JOURNAL. On page 46 the illustration Fig. 2 is misrepresented as the Critical Points of Iron. This should read "Fusion diagram continued."

Castings Used in Ship Construction.

STERN FRAMES.—No. II.

By Ben Shaw and James Edgar.

The Pattern-Making.

The stern frame about to be described is a type used in single-screw ships. It will be noted that this frame has a quick slope on the bottom trough, which minimises the risk of the casting being broken, as no matter how the vessel may be trimmed by the stern it will be clear of the lowest point. The casting is as much a shaft bracket as a stern frame. On each end of the bracket are flat flange pieces to which the wrought-iron portions are joined. Fig. 1 is a section through the centre of the "arms," which, although an incorrect term, we may conveniently use in this article. It is drawn as it will be in the ship. While the flange

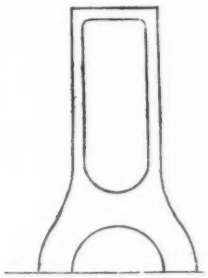


FIG. 4.

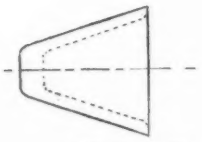


FIG. 2.—END VIEW AT B.

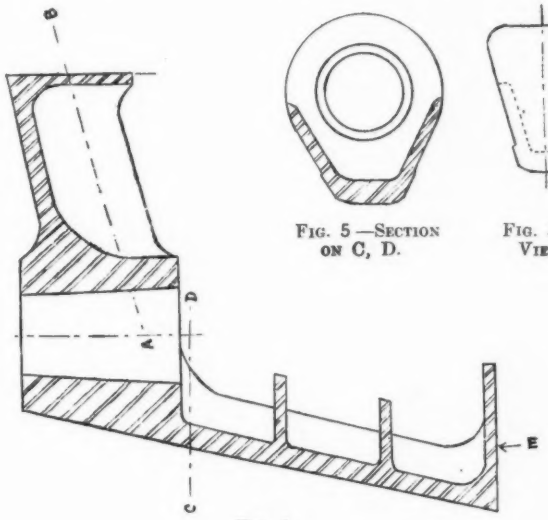


FIG. 1.

FIG. 5.—SECTION ON C, D.

FIG. 3.—END VIEW AT E.

at E is raised above the trough, that at B is practically the same height. The section on AB (Fig. 4) is given to show how inside the trough a large fillet is formed at the junction with the boss, thus graduating the metal from the boss to the arm. The bottom arm joins the face of the arm as shown in Fig. 5, and the bottom metal simply forms an extra thickness on the boss.

This is a rather difficult pattern to make. It would not be practical to box both arms up and core out the troughs, because of the labour involved in the pattern-shop, so that method will not be discussed here. The problem which the patternmaker has to solve is how to construct the pattern so as to give the maximum strength. If the arms are not built on to the barrel they must be so securely fastened that they will not sag when it is being handled. It may be profitable to glance at finished patterns first. Fig. 6 shows a pattern constructed with the arms built on to the barrel, the lagging of the arms forming also the lagging of the barrel. Fig. 7 shows the other method of construction, the barrel being built independently of the arms and the arms built against it, and supported by thick battens—preferably of hard wood—shown by the dotted lines. The latter way is very much cheaper, and provided only one casting is likely to be required quite satisfactory, but if the frame is for a standard type of ship, and consequently the pattern will be used many times, it cannot be too strongly made. We shall describe the better form of pattern first.

The job would, as usual, be set out on the floor or building board from the template supplied by the mould loft, and the usual construction would have to be added. Figs. 8 and 9 show the best form of barrel The grounds should be about 4 ins. less in diameter than the finished barrel. This may be thought to make an excessively heavy pattern, and that a lesser thickness of lagging would suffice, but it must be remembered that the arms are long, and the thickness of the metal will probably be not less than 2 in., and to reduce the lagging from 2 in. to 1 in. when it reaches the barrel would not be conducive to strength, and there would be no saving of timber, as it would be sawn or gouged off. In the illustrations the grounds are not shown made of segments, but of two thicknesses crossed, a form adopted because of the number of checks that will be cut out for longitudinal stays. The segmental method could be used, however, the segments being kept sufficiently wide for strength, and a tie batten built on the centre line. If cross grounds are used they should not be less than 2½ in. thick, and for each half the three ought to be screwed together and finished thus. The reason for the large number of stays is to make a good bearance for the lagging, a portion of which will not rest on the grounds at all, but solely on these stays. The skeleton half-barrels ought to be dowelled together before the one half is set in position on the floor to begin building.

In addition to the ribs or stiffeners inside the trough, which will serve the purpose of grounds, additional grounds will have to be used. In Fig. 10, A and B are shown as additional grounds. It is a simple matter to get the shape at any section of the trough for these grounds. Lines representing the top and bottom of the

trough are set down, and then the width at any section is obtained, and the depth can be got from the floor-view corresponding to Fig. 1. As the grounds will have to be removed afterwards and the ribs likewise it will be difficult to do much finishing afterwards. When the half-barrel and the grounds are screwed to the floor the building of the arms can be proceeded with, beginning with the top arm. In the sketch all

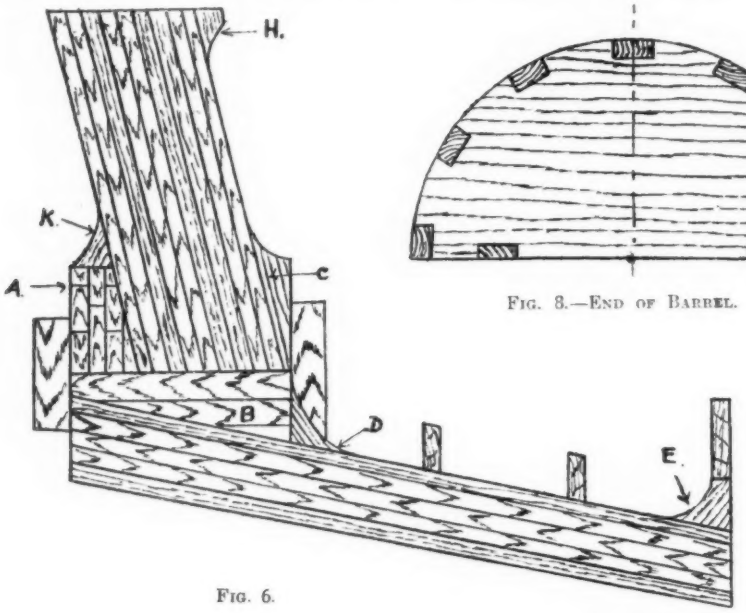


Fig. 6.

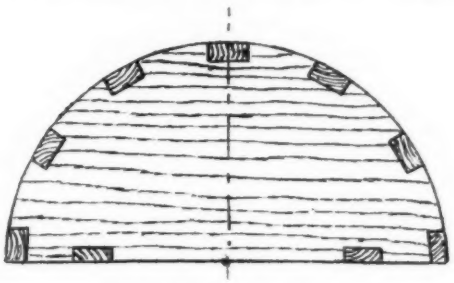


Fig. 8.—End of Barrel.

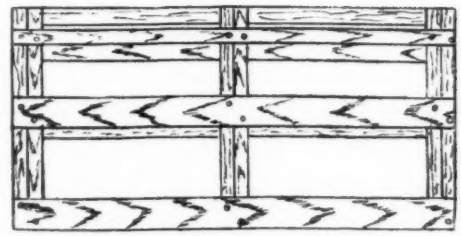


Fig. 9.—Front View of Barrel.

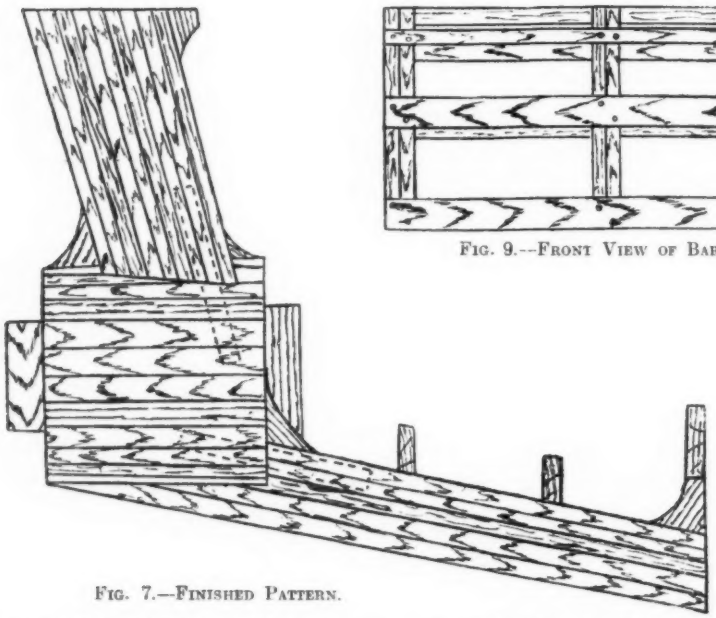


Fig. 7.—Finished Pattern.

will have to be left loose for the moulder, care must be taken when building that no glue gets on the edges. Each piece of lagging after it has been bedded on the grounds should be finished off on the inside, for as a result of the arms not being removable from the barrel the top stays have been left off to make it less complicated. A good base for the top arm is formed by screwing the joint piece A, Fig. 12, right across the barrel. It has to be checked over the stays, and it ought to be made of hard wood. Fig. 11 shows it

checked and ready to be screwed down. This is much superior to butting it against the barrel and relying on a pocket screw, and as it takes but little time it ought to be done whichever method of construction is adopted. The lagging, which should be about 2 in. wide, can now be built on. It will be necessary to cut each piece separately, and although no joints are shown in Fig. 6 it may be advisable, in order to save timber, to make the lagging in two or three short lengths, crossing the joints as in ordinary segmental work. It is well to build the arms to the centre of the barrel. If a little ingenuity is displayed by the craftsman in breaking

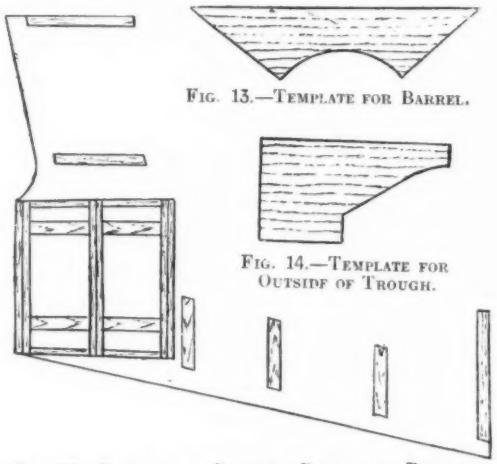


FIG. 10.—BARREL AND GROUNDS READY FOR BUILDING.

FIG. 13.—TEMPLATE FOR BARREL.

FIG. 14.—TEMPLATE FOR OUTSIDE OF TROUGH.

FIG. 11.—BASE PIECE OF TROUGH.

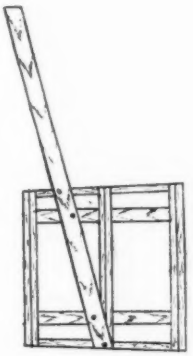


FIG. 12.—SKELETON OF BARREL, SHOWING BASE PIECE OF TROUGH.

out timber there will be a great saving. Each piece will be a guide when cutting the next piece, and after it has been roughly sawn it can be placed in position, and by the use of hermaphrodites, the calliper end resting on a ground the scriber end timber may be marked. Of course, the lagging should be well screwed, and there ought to be enough thickness to ensure that when the outside is being finished the metal will not be thin. The bottom arm is built in a similar fashion to the top arm. The base, however, is not checked on to the grounds, but fitted to them, and made flush with the end of the barrel, and lagging may be made in short lengths as with the top arm.

The barrel can now be completed, as there are parts

FIG. 15.—FINISHED PATTERN. END VIEW.

which have not been covered by the lagging. The part at A, Fig. 6, is most easily filled with a segmentally-built piece, which can be finished inside and out at the sandpapering machine. But the part B, which is wedge-shaped between the two arms, can be filled in with ordinary staves. The piece C can be cut from solid timber.

The outside of the pattern will require some finishing off, and for the purpose it is better to lift it on to trestles, or legs of the same length screwed against the several faces. Planes and spokeshave will have to be used. The adze is often used on this class of work for roughing off, but unless by the expert it is awkward to use. The best tool for the patternmaker to use in roughing down work is undoubtedly the crank gouge. The knuckles do not knock the timber as when using an ordinary gouge, and it can be used comfortably in any position. The diameter of the barrel can be drawn on the ends and a straight-edge can be used from end to end when finishing part of it, but towards the arm fillet a template like Fig. 14 had better be used. For the outside of the arms, templates the same as those described in the stem piece article (like Fig. 15) will have to be made. The corner pieces, D, E and H, should not be screwed on till the shape is finished off, and a solid block ought to be fitted for the fillet K behind the top arm.

It will be observed, looking at Fig. 16, that the end flange is made to the inside of the trough metal and carried straight out, a piece being afterwards screwed on at the ends to make it in line with the outside of the metal. This is a better way than cutting it from one width of timber, as it allows greater freedom when building the arm. The thickness which forms the rebate on the bottom arm is not shown in Fig. 6, but it presents no difficulty. The barrel as it will appear on the outside face is shown at Fig. 17, and a joint view is shown at Fig. 18 The large fillet at the junction of the top arm with the barrel has still to be made, and also the smaller fillets which strengthen the end flange. The latter should be made in three or four parts fitted in first, when they can be removed and gouged, using a template. It might be made skeleton style, leaving the moulder to complete the fillet with sand, but no great saving will be effected in the long run. The large fillet must be made of solid blocks. The prints on the ends of the barrel may be boxed up or made solid, and ought to be 3 in. or 4 in. thick. This finishes one half of the pattern, and the other half can now be built on top of it. A stay may be screwed across the faces of each half, which will bind the arms and the boss. It should be about 1½ in. thick and dowelled.

The form of construction illustrated in Fig. 7 is easier. The barrel is lagged, as shown in Fig. 19, and not as many stays are needed because the arms will butt against the staves.

The lagging should be closely fitted against the boss, and each piece should be pocket-screwed to the boss. Some reliance will have to be placed on the large fillets between the arms and the boss, so they must be well fitted in segments, and both glued and screwed. The

fillets are not shown in the sketch Fig. 7, but additional means have to be used to keep the arms rigid. In Fig. 7 top battens are indicated by dotted lines. They should be long and 3 in. or 4 in. square, and with plenty of taper on both sides and ends. The moulder will not remove these, but simply make up the space left by them after the pattern has been drawn from the sand. The inside of the arms will be finished in the same way as for the other style of pattern.

This design lends itself to quick production, because quite apart from getting the timber ready, men can work quite independently on each arm. If the foundry were to insist on the arms being cored, which as has already been said, is very unlikely, the methods that it would be necessary to employ have already been described in previous articles.

The boss core would be run up with a horizontal board like Fig. 20, and when the fillets have been painted inside the arms the work is ready for the foundry.

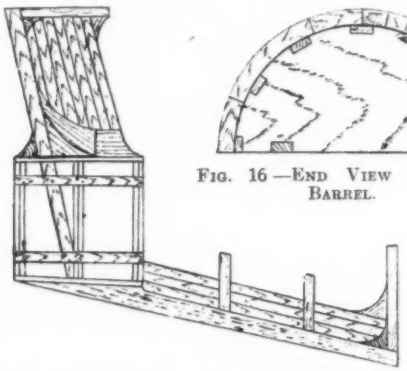


Fig. 17.—Joint View of Finished Pattern.

Fig. 16.—End View of Built Barrel.

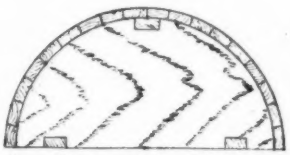


Fig. 18.—End View of Barrel.

Fig. 19.—Board for Core.

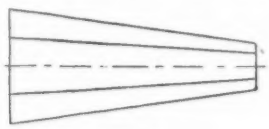


Fig. 20.

Stern Frames No. 2.—The Moulding.

The type of stern frame herein described is more general in connection with cargo vessels. The tendency is towards simplicity of design, while retaining the requisite strength. The desire for economy, not only in the use of labour necessary to construct the vessel, but in charges which occur through damage after the vessel has left the builders, has necessitated more careful consideration to the design of parts in the structure liable to fracture. The need for the additional care is not so much in the resistance of possible fracture, though that is, of course, a consideration, but in diminishing the area of its influence and thus reduce to a minimum the expenditure of repairing the vessel. It is in the general shape of some of the castings used in the construction that alterations are being made, especially in the stern frames. It has been customary to have very large stern frames for cargo vessels, comparatively plain in design, but taking up the whole of the stern sometimes as one casting.

Experience has proved that, when a vessel so constructed, through collision or grounding, fractures the stern frame, considerable expense is incurred in its replacement, because, not infrequently, the nearest port to which the vessel is taken for repairs has not facilities for turning out a large steel casting. Hence for this type of vessel a smaller form of stern frame is gradually being introduced, which limits the size of the casting to a minimum. From an economical point of view the design selected has many advantages. It is not liable to fracture, but should fracture occur it can be more readily replaced and less labour is involved. Also many iron foundries have extended their plant and are capable of dealing expeditiously with castings about this size, thus increasing the number of possible producers, which, as a rule, reduces the time in which a suitable casting can be supplied.

In making such a casting speed is important, although that is of little value if the soundness is sacrificed. The type lends itself to being cast on an incline, and since substantial risers would need to be brought from the boss, the end of the box nearest to the boss is raised. Such a method requires a two-part box, and if available a built box is more suitable. Some foundries prefer a deep drag sufficient to take the full depth of the frame, in order that the joint of the mould will follow the top contour of the pattern and down to the centre of the boss. Such a method increases the top lift considerably, and requires additional support to carry the shape. The method is advantageous in that the joint usually coincides with the top of the drawbacks necessary to form the channel sections. Other foundries display a preference for box parts having the depth of both drag and cope approximately similar, so that the mould may be formed into two symmetrical halves coinciding with the joint of the pattern. This method offers the advantages of a level joint, and, since it is more easily prepared with less labour, it is more frequently resorted to when boxes are available. It has this disadvantage, however, that the drawbacks project well above the joint, and necessitate considerable care in closing. The disadvantage can be minimised by the use of long guides, so that when closing these will be engaged before the cope comes into contact with the drawbacks.

The practice of bedding such a job in the foundry floor is still prevalent. This method necessitates equally as much labour and increases the number of risers required when casting, without necessarily being able to obtain a sounder casting as compensation. When facilities are available and the size and character of the work admits, it is profitable to use a two-part box, so that the work may be cast on a gradient; such a method is adopted in this instance. A level bed is prepared on the foundry floor upon which the bottom half of the pattern is laid, joint down, as shown in Fig. 21. This increases the reliability of the pattern, especially if it is of a fragile nature. The box part

may be set in position to locate and determine the shape of bars which will be required. While these are being sorted out or prepared, sand prints can be formed for the drawbacks. Bricks are used to build up the shape, packing up under the web to give support while ramming, and shaping up the prints with floor sand. Well damped sea sand sleeked over the prints makes a good parting. The shape of these prints should follow the contour of the inside of the web, as shown in the sections on AB and CO. Fig. 21 shows the pattern made up with the improvised prints, the inside boss print, which is shown, would be partially covered with the sand print. The elevation shown in the sketch illustrates the relationship between the box part and the pattern with the boss removed. When the bars are fixed the ramming can be commenced, covering the pattern with the prepared composite and then backing with the floor sand. Providing the bars have been made to follow the shape of the pattern and about ¾ in. to 1 in. from it, no additional stiffening to the sand need be used. A certain amount of nailing is advantageous afterwards when the pattern is withdrawn, but these are not necessary to support the sand while preparing the mould.

When the box is rammed up and levelled off the whole may be rolled over, but it is necessary to retain the pattern in position, hence screw eyes should be fixed in so that a temporary safeguard can be assured against a bad lift. The improvised prints will, of course, remain on the bed, and with a good sleeking their impressions in the box will be ready for commencing the formation of the cores and drawbacks. The clear sides should be well tapered, and have a good application of parting sand, as also should the sand bottom. Before a commencement is made with these cores it is advisable to try grids in with the top half of the pattern in position, so that they may be afterwards set to conform with the general shape of the pattern. Suitable forms of grids for this purpose are shown in Fig. 21, and, while the ordinary prods or

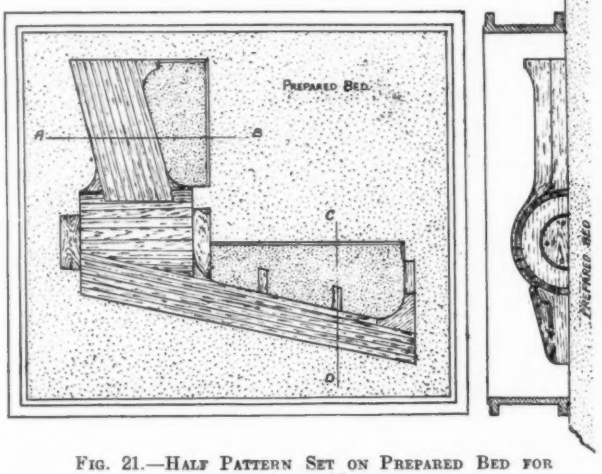


FIG. 21.—HALF PATTERN SET ON PREPARED BED FOR ROLL-OVER METHOD.

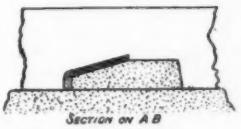


FIG. 22.—SHOWING THE MAKING UP OF A CORE PRINT.

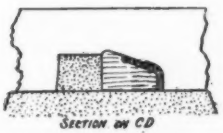


FIG. 23.—THE PRINT OF THE CORE.

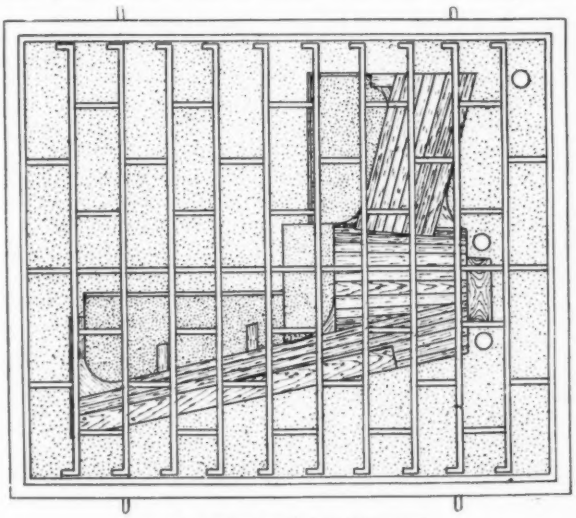


FIG. 25.—COPE ARRANGEMENT.

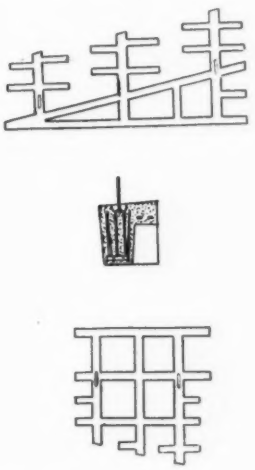


FIG. 24.—DRAWBACK GRIDS.

gaggers can be cast about the outside of these, it is safer to cast pieces of iron in those parts of the grids which support the sand near to the pattern, as they are more pliable and can be bent to shape when forming the cores; furthermore, they offer less resistance to the crushing of the cores when the metal in the mould has solidified. In designing the grids necessary it is important to keep in mind the crushing section, and keep the ends well clear, so that no solid substance will be a barrier against the strain of the casting. The top half of the pattern is removed and a bedding of wet composite applied for the drawbacks into which the grids are set. Proceed to form the shell of the cores with this compo about 2½ in. thick, and ram ashes inside, gradually forming up the complete shape of the inside portions, to allow the top half pattern being bedded over them. A small drawback is required over the top half of the centre core point, cutting through the long drawback to the joint, as indicated in Fig. 25. This is necessary to allow the centre core being lowered into position when closing. The small drawback can be made to follow the contour of this boss and the tops of the other two drawbacks with which it comes into contact, and then graduated off to reduce the surface likely to interfere with a safe lift of the cope box.

When all the drawbacks are made up and allowed to stiffen, the cover box is set and the work of ramming proceeded with. Gate-sticks require to be set to provide a runner near the junction of the rudder post and two substantial risers from the boss. These should be given a rake so that they will be practically vertical when the job is canted for casting. After the cope box is rammed up the same practice is resorted to in temporarily securing the top half of the pattern to the box, the ribs in the bottom coreback and the inside centre core print having been previously loosened, so that they remain in the bottom when the top box is lifted. When the lift has been accomplished and the box rolled over, the work of stripping the mould of the pattern can be commenced. Some patching will probably be required to be done to the drawbacks left in the bottom, but a clean withdrawal should be obtained from the pattern sections. The removal of the drawbacks carrying loose sections of the pattern will clear the bottom half of the pattern. When the mould is stripped and sharp corners of sand not essential are rounded off the whole job can be transferred to a drying oven. It is well, however, to depress the joint surrounding the mould, and cut out a number of contraction webs while the sand is green. A riser can be brought off the uppermost point of the boss, but since risers are connecting with each side a depression at the highest point can be made in the cope, so that any gases which may be trapped will not interfere with the soundness of the casting.

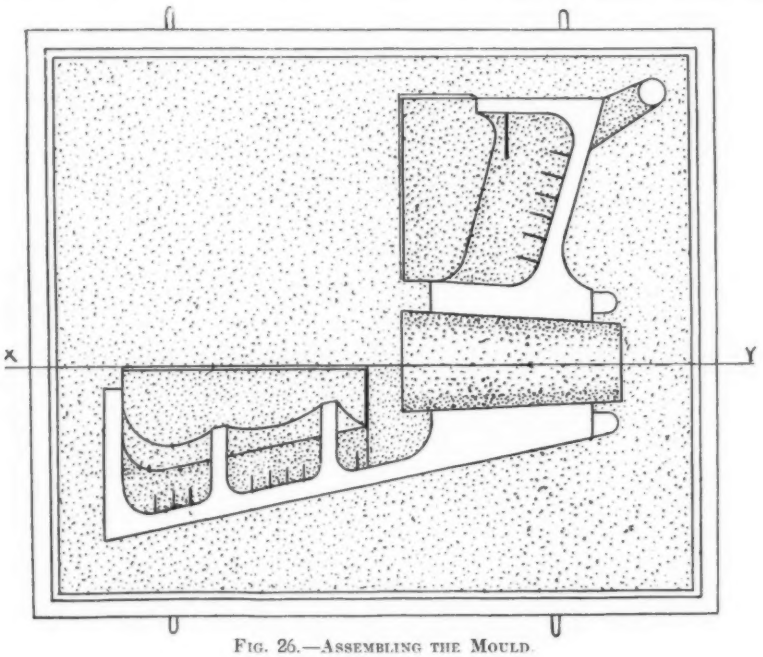


FIG. 26.—ASSEMBLING THE MOULD.

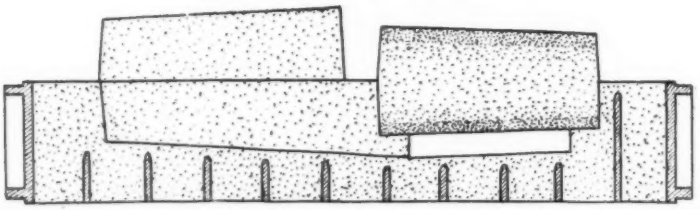


FIG. 27.—SECTION ON X. Y. WITH CORES SET.

It is customary to prepare the runner and riser basins and the centre core while the mould and drawbacks are being dried. The centre core is usually made on a horizontal spindle in a manner such as has been described in previous articles, iron rods being wired on before receiving the last coat of composite to give strength to the core.

When such a job is cast on the slope and the runners and risers are localised a single trough is frequently used for taking what runners and risers are necessary. It consists usually of a rectanglar plate having a slot along the centre, snugs about the outside for handling with a crane, and surrounded with a series of gaggers. The runners and risers are shaped inside of these and are independent of each other. Bricks and composite are used to form the shape, the gaggers serving to enclose the whole. Both centre core and runner are dried.

When all are dried and thoroughly cleaned up a good application of silica paint is given to those parts with which the molten metal comes into contact, and the whole are re-stoved until they are thoroughly dried. On removal from the oven, the assembling of the box lowered into its relative position, the whole requires to be wedged up preparatory to casting. There are a wide variety of ways adopted for securing the box parts, the method shown in Fig. 28 supplying ample safeguard against the pressure exerted by the molten metal. A number of clamps are illustrated, the end ones being capable of adjustment, one of which is tightened by a tommy bar, the other by wrought-iron wedges. The inside clamps here shown require packing at the bottom, and then the use of wrought-iron wedges at the top for tightening. The joint flanges are also secured by bolts as shown. When the box parts have been firmly secured together, the whole is tilted and packed up as shown in Fig. 28. Then a composite bed is prepared for the runner and riser trough, a plan of which is illustrated in Fig. 29. The preparation of this bed requires considerable care, gate-sticks being set in the existing orifices, completely filling them, to prevent any sand falling into the mould. After the bed is made up, the trough is lowered upon it, so that the runner and risers coincide with their basins, the inside junction is made up and coated with silica paint. Red-hot cast-iron plugs can be used for

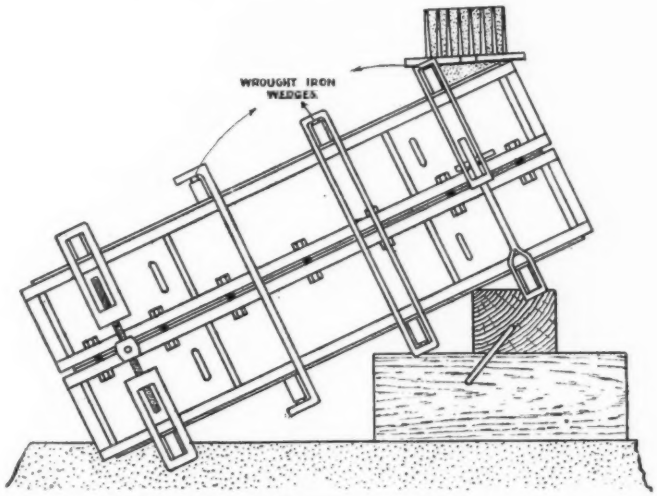


FIG. 28.—ARRANGEMENT FOR CASTING AT AN ANGLE.

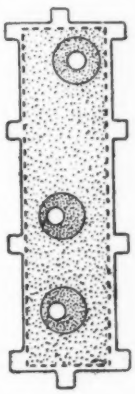


FIG. 29.—RUNNER AND RESIN TROUGH.

mould can be proceeded with. The two larger drawbacks can be lowered into their respective positions, a couple of chaplets being nailed to the bottom of the mould equal in thickness to the required web in order to maintain the balance. The holes about the staples are then made up, and dried, by means of a hot brick. The centre core requires to be placed next, the top half of the small end of this core being rubbed back to allow clearance for final closing of the mould. The use of a belt slinger is invaluable in handling cores of this kind.

The last part to be lowered is the small drawback covering the inside end of the centre core. Fig. 26 shows a plan of the mould assembled, excepting for the small drawback, the contraction webs shown by thick lines, and the shape of a thickened fin shown in contact with the webs of the frame and the divisional brackets. A section of the assembled mould is shown in Fig. 27, showing the clearance necessary on the parts projecting above the joint to prevent any possibility of crushing when the cope box engages them. A section of the small drawback is shown in this illustration also.

When the mould has been assembled and the cover drying these, remaining in until just prior to the pouring of the metal. When the job has been cast the boss should be fed by way of the two headers.

It is necessary to give considerable attention to the easing of a casting of this description, the flanges connecting the keel plate and the rudder post are large and at right angles to the strain set up when the metal is cooling; hence the drawbacks must give to the pressure. Few of these drawback grids offer suitable facilities for the wedged bar holding grids until the wedge is withdrawn, a practice which is very valuable in easing a number of steel castings, so that access must be obtained to ease by hand. It is not necessary to wait until it is convenient to lift the cope box; the drawbacks can be located from the outside and the sand and some of the short bars removed in order to get at the drawbacks and ease them so that they offer as little resistance as possible to the casting.

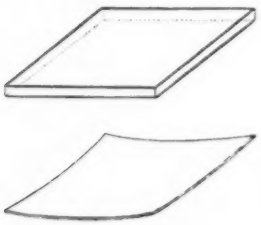
However much the casting may be eased, internal strain is bound to be created in the casting; the effort is necessary, however, to minimise this strain so that its amount does not exceed the strength of the metal to resist it. By careful attention in annealing practically all strains can be removed.

Stresses and Strains on Light Castings.*

By A. Fraser.

The writer's object is to bring to notice the conclusions formed from a period of close observation, and the results of a large number of experiments made by himself some years ago, with the idea of obtaining some reliable knowledge as a basis from which a beginning could be made to study the seeming vagaries of bent, broken and twisted light castings in grey iron. No claim is made that the paper is an accurate and scientific treatise on the subject, as most of the observations and experiments were made under everyday foundry conditions. The results of different methods of ramming, placing of "gits," placing in the moulding box, and alterations of sections and contour of patterns were examined more closely than usual and tabulated, but few really fine measurements were taken.

The casting defects mentioned above are all due to stresses set up in the casting during the cooling, and are common, in varying degrees, to all castings in any metal or alloy, but in no phase of foundry work are they so noticeable or so destructive as in the production of light grey-iron castings. The sections of the industry in which one has to pay particular attention to those defects are the manufacture of stoves, grates, sanitary ware and builders' ironmongery.



FIGS. 1 AND 3.

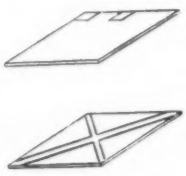


FIG. 2.

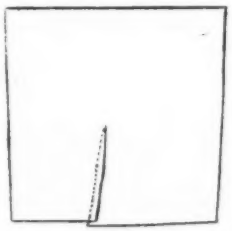


FIG. 4.

The chemical composition of the irons used has an influence on the amount of distortion and breakage, but however this may be changed and altered, very little progress will be made towards controlling or eliminating the defects by this alone.

The reason why light castings are mentioned in particular is because they show distortion on a much smaller area of surface than a heavier casting would, although the stresses in both are approximately the same. Fig. 1 should explain the reason for this. The upper portion is intended to show the behaviour of a plain casting of, say, 18 in. to 2 ft. square, and 1 in. thick. If moulded properly it should turn out straight and true to pattern. The lower portion of the slide shows a casting of the same superficial area, but only 3/16 in. thick. The mould for this casting would be quite straight and true, yet the result be a casting with all its edged curved. The reason why the one is distorted and the other not, is that the cooling stress in each case is about the same, and although it is sufficient to bend the thin casting, it cannot overcome the rigidity of the thicker one. It may here be mentioned that the curves and angles on this and other illustrations to follow, are exaggerated considerably, so that the argument may be more easily followed. A few examples of the simplest strains as the result of uneven cooling will be given, and as briefly as possible an attempt will be made to explain their causes.

Fig. 2 shows a common open-sand plate of fair size and thickness. When a casting of this description has been cast and the cooling is observed, it will be seen that the parts which cool most rapidly and discolour first are the corners. The discolouration moves gradually along the edges and inwards, the centre being the last to cool. In most cases, however, this cannot be seen, as the practice of covering the plate with sand and then forming a diagonal channel by stripping the sand from corner to corner of the plate to a width of 4 to 6 ins. is usually followed. The theory underlying this practice, which is quite sound, is that the heat in any body, or in any other bodies in contact with it, tends to a state of equilibrium throughout their parts. As it is generally accepted that the corners lose their quota of heat most rapidly, this tendency to equilibrium must cause a flow of heat from the hotter portions in immediate contact to these quickly cooling corners. The result of the casting losing its heat in this manner is that the middle part of the plate is hotter at any period of the cooling than any other, and therefore when the sides or corners have reached atmospheric temperature, and have finished contracting, the centre has still to take a fraction of its total contraction. As this centre and the edges are held rigidly together by the cohesion of the metal, there is a resistance to any isolated contracting movement within the casting. The greater the difference there is in the times of the cooling of the parts mentioned the more one of them has to contract after the other has finished, and therefore a greater force is required to enable the laggard part to retain the position and state of stability it seeks.

If the stress set up in the casting is of a mild nature no strains will be observed; the casting is quite good to look at, and will probably do all that is required of it. The stresses in it, however, are never at rest; parts of it are in tension, and parts in compression, and a blow which would have no detrimental effect on a casting in a state of equilibrium may cause this one to crack or break. If the stress is greater than in the above case the

* Read before the Coventry Branch of the Institution of British Foundrymen, November 28, 1917, Mr. E. Broughall in the chair.

centre may crack away at some part from where it is held outwards by the sides, thus regaining some more freedom for its inward movement; or it may reach the position it seeks by bending or buckling the edges slightly. If the edges are too rigid and strong to be bent the centre releases itself by cracking away from them.

If the foregoing has been made clear the necessity of hurrying on the cooling of the centre will be realised, and the value of the practice of making channels in the sand coverings should be apparent. A query may arise in thinking about this. Would not a right-angled channel from the centre have served the same purpose? No doubt it would, but not so efficiently as a diagonal. The study of the small squares shown on this illustration will show one of the reasons why. Suppose those rectangles to be 6 in. square. They are free from the sand which is covering the rest of the plate; and when bodies of different temperature are in contact, some of the heat of one is transferred to the other until a state of equilibrium is reached, always allowing, of course, that one of them is above atmospheric temperature. This transference of heat is more or less rapid, according to the amount of surface contact there is between the bodies. The area of both squares exposed to the cooling action of the atmosphere, and the contact of both with the cold sand underneath is the same, but the one on the corner has 12 in. contact at its edges with the colder body, whereas that in the middle has only 6 in. This partly explains the more rapid loss of heat at that point.

Fig. 3 is intended to show in a slightly exaggerated form the shape of a plate casting of, say, 2 ft. 6 ins. square, 3/16 in. thick, cast in a perfectly straight mould, and of even section throughout. The warping seen on the plate is the result of the more slowly cooling centre drawing the edges in with it to a smaller area. Castings of this size and area bend easily under a little force, and a casting bent like this is proportionally stronger, and the destructive internal stress much less than in a casting of the same superficial dimensions, made under the same conditions, which has taken no bend.

It is a fairly common occurrence in foundries making this class of work to see castings similar to this come out of the mould in pieces. This happens usually when a change, intended or otherwise, has taken place in the composition of the metal, making it of a more rigid and brittle nature, and therefore not giving way easily to bending or the drawing inwards of the centre. It is not that the metal in the castings which break is weaker than the other; this has been tested by the usual physical tests many times, and in all cases that came under notice the metal in the broken castings was the stronger of the two.

Fig. 4 shows a similar casting to the last, and under the same stresses, which has been broken carefully so that the break only reached to the centre or a little beyond on one side. This break will not open, but will appear as a crack. If then the two sides of the crack are pressed apart in opposite directions so that they are separated near the centre, and then released, they will come together in the manner shown. This is an infallible test for a slow cooling centre, but it takes a casting of fair size to give the distinct overlapping effect shown. In referring to the particular casting stresses which have been already mentioned, the usual refrain is "one part of the casting contracting before another." This is quite right, but it has to be qualified by saying "one part of the casting contracting before another at a certain period during the cooling."

To the mixtures of iron used on this work, and probably all mixtures with slight variations, the stage in the cooling about to be mentioned is applicable. Uneven cooling, and therefore untimely contraction, takes place in all castings from the moment of the first solidification, but down to a certain stage this does not set up any permanent internal stresses. The relative position of the cooler edges to the hotter centre as cast (or *vice versa*, with other castings) are being altered every second. The edges are moving towards their centres much more rapidly than is the middle of the casting, but they do not draw the latter with them as might be expected down to the stage in the cooling mentioned. There is a certain amount of crystal grain freedom and plasticity in the structure building of the iron at this period, making it so that it will sustain a certain amount of violence and rough usage, and yet retain its strength and cohesion. The place relationship between a crystal and its fellows is not fixed. The crystals can and do move (to a limited degree, of course) among themselves at this period, their freedom becoming less as the cooling advances, until the stage is reached when practically no further movement can take place without rupturing the structure, which means a tear or flaw in the metal. It was ascertained that this stage corresponded roughly to about 700 deg. Centigrade, or just before the part of the casting under examination lost its last red colouring.

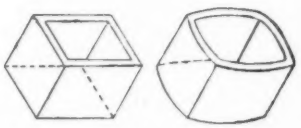


FIG. 5

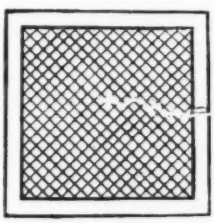


FIG. 6.

FIG. 7.

Some proof of this assertion may be seen in Fig. 5. It is a sketch of a plain open-ended box casting, pattern and mould being perfectly rectangular, although it would have been better for the purpose of this example if it had not been so deep. A square frame 2 ft. 3 ins. deep would have served, as there are stresses in a casting like that shown in the sketch, of which mention need not be made at this point. The first of the illustrations shows the shape of the casting as moulded.

The second shows it as it comes out of the mould when cold. The curves on the sides are entirely different from the others that have been previously examined, in that their formation leaves little or no stresses in the casting. They are formed by the resistance of the enclosed sand to the four shrinking sides at a stage of the cooling when there is that freedom of movement in the structure of the metal already mentioned. If when a casting of this kind is cold it is cleared of sand on the outside only, and the curves on the sides are measured, and then measured again after the packed sand in the middle has been removed, the curve will be found to have decreased considerably, the amount of decrease corresponding to the deformation after the metal has passed from the first state to a more elastic condition.

Fig. 6 shows a stress acting in the opposite way to that shown in Fig. 4. The casting is a grating with a solid border. The latter takes longer to cool than the perforated part. When the border is nearing the completion of its contraction movement, it puts a severe compression stress on the interior, which, resisting this strongly, puts the border in a state of tension. Very often a casting under this stress will break in the mould. If it does come out whole, a comparatively slight shock will break it, the flaw penetrating well inwards, and the casting springing open at the edge. If the border and centre are very much out of balance, by which is meant that tensile strength of the solid edges is greater than the strength of the centre under compression, the latter will bend a little, and then shatter into a number of pieces, the border remaining whole.

Fig. 7 shows the effect of a flange cast on to a plate casting. It will be seen that the three plain sides act as in other examples, but that the flange has made the side on which it is placed curve in the opposite direction. With the knowledge of how all the curves on this casting are formed, anyone should at once be able to tell by looking at the sketch how the plate was moulded, that is, whether the flange was on the bottom side of the pattern during the moulding process, or on the top side; yet it is a regrettable fact that a very small percentage of foundrymen could give this information without making a close examination of the casting itself. This casting, to be of this shape, could not be cast otherwise than with the flange in the bottom of the mould. To explain why a flange curves because of uneven cooling, it should be noted that the most rapidly cooled side or edge of it invariably occupies the convex of the curve. Whether the flange is in the top or in the bottom of the mould this is equally true; it will curve upwards in the one case, and downwards in the other. When the sides of a plain plate casting curve without the complications of a buckle or twist, they invariably curve upwards at their centres in ordinary moulding practice. It has been found that they will bend downwards, but only by the moulder exercising some ingenuity, and departing considerably from regular foundry practice.

Fig. 8 is a sketch of the same plate, but with two flanges instead of one. It is bent on its three free edges as before, but on the fourth it is practically straight. The quickly cooled edge of the one flange is struggling to bend one way, and the edge of the other flange the opposite way, both with the same amount of force, the result being that they hold each other straight while creating a severe internal stress. It may be thought that the entirely upward bending tendency of the edge on which they are fixed would help the one on the top side of the mould, but if we consider that this is caused by the edge cooling more rapidly, and that now additional heat has been placed here by making it the junction of the flanges, we see why this does not occur.

Figs. 9 and 10 are just to amplify what has been said, and to illustrate the numberless modifications of castings to which the reasoning as to the curvature of flanges does apply. Fig. 9 shows an ordinary roof gutter, and it can be visualised as if it were only two flanges connected at the top. It behaves as would be expected, the whole casting taking on a gradual curve of considerable dimensions. A camber of ½ in., and often more, is allowed for this distortion. The method of running those articles is shown in the figure, and, with a little thought, it will be apparent how this method increases the curvature, although a better method has still to be found.

Fig. 8.

Fig. 9.

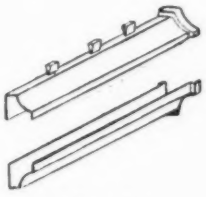


Fig. 10.

The same reasoning applies to Fig. 10, with this reserve, that the two edges do not take the same amount of curve, the straight side bending most. The addition of a quickly cooling sharp corner on the other side affects the curves on the side where it is placed, also making that side curve slightly in a lateral direction. On some modifications of this design, this lateral distortion is quite visible; on others the strain cannot be perceived, but there is no doubt an extra stress is set up in the casting by that sharp corner.

Internal stresses can be reduced by modifying the sections of castings and altering design, so that a more uniform cooling takes place, but the first would often entail making a casting too heavy or too light for the purpose required, while alteration to design has sometimes to be limited, for the sake of both economy and appearance. Therefore the question arises, to what extent can the strains, as represented by the curves, be controlled; or can sufficient accurate knowledge of them be obtained so that they can be allowed for in the patterns, and thus eliminate some of the preliminary work usually done on trial castings.

A number of experiments were made to determine what controlled the direction of a number of those curves, and all information gained from them went to prove that the most rapidly cooled part of a casting which curved always occupied the convex side of the curve. With a little explanation Fig. 11 should show the niceties of the influences controlling the direction of the curves. This is a sketch of a frame casting having broad and narrow sides, with a chill placed in the mould against the edge of the narrow sides to accentuate the cooling at that point.

During the early stages of the cooling the casting takes the shape of the lower sketch, as will be understood from earlier examples. But, seeing that when the metal becomes rigid both sides of the frame should be of approximately the same length when cold, there must be either a stretching on the broad side, a bending on the narrow side, or a breakage, so that each of the parts may obtain their objective. What usually happens is that the narrow side bends upwards in the mould. If a very slight chilling be given in the mould to this narrow strip on the bottom side it will bend downwards.

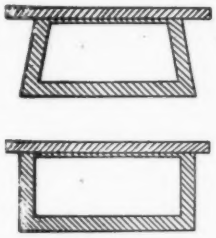


FIG. 11.

FIG. 12.

FIG. 13.

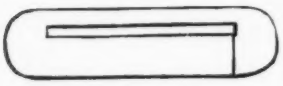


FIG. 14.

FIG. 15.

FIG. 16.

If the chilling be applied as in Fig. 12, the bending will occur as here portrayed. There are complications ensuing from this last curve which vitally affect the casting, but which need not be gone into for the purposes of this paper.

The point to be noted in the foregoing examples is that whether extraneous or artificial influence is used or not, a curve caused by a stress bends upwards in the mould. The only explanation for this is that the top of the casting cools more quickly than the bottom. In some of the experiments a downward movement was obtained by heating the top half of the mould, and casting immediately. Also, the position of the casting in the moulding box has an influence on this curve.

Fig. 13 is the same as before, but the castings in this instance were cast in a much more brittle mixture of iron which would not give to the stress in the same manner as the last. Some of them broke in the mould, others came out whole, but a slight blow or shock caused them to fracture, a peculiarity of this fracture being that another broke on the narrow, or what appears to be the weakest side. Searching for a reason for this, the conclusion reached was this: the narrow side is under a compressive stress, the broad under a tensile; the compressive strength of a cast iron is approximately six times that of its tensile, and, as the two sides do not show that variation, the heavier section was the weaker of the two.

Fig. 14 is a sketch of a casting which has been kept as a curiosity, since the foregoing experiments were made. It shows better, perhaps, the features aud properties of such castings as described in the last illustration.

Fig. 15 shows a curve which cannot be produced without artificial aid, and is seldom seen.

In Fig. 16 an attempt has been made to show what is commonly called a "twist" or a true buckle. The curves on the opposing edges of the plate casting shown earlier were parallel to one another, but no two curves on this plate are. It is a strain more difficult to deal with in the foundry, as it is more often than not unstable in its shape. On examination of a twisted casting being made it will be found that two of its corners are curved upwards and the other two down. The next time of making this casting it may happen that the two corners which were up in the first case are now down, and *vice versâ*. Also, with a perfect balance of the opposing stresses a peculiar effect is produced, the contour of the casting radically changing with a slight explosive noise when a little pressure in the middle of one side is applied to it. The discovery of the cause of this strain was a lengthy affair, as theories previously formed regarding it did not work out in practice, but the conclusions formed as a result of the experiments were, in short, these:—A twist is produced by the edges of the casting not cooling so rapidly as the centre, but the difference in the rates of cooling must not be great otherwise. The centre is crushed into an even domed shape which keeps the sides parallel. It should be apparent from this that the main feature in the formation of a twist is that the resistance to bending of a part of the casting is nearly, but not quite, equal to the stress opposing it. By working on this information, and with a little experience, a twisted casting can be made at will.

Figs. 17 and 18 show the method used to alter sections for the purpose of the experiments. In the one case they are squares of paper graded to size and pasted on the top of one another in the centre of the pattern. In the other case they are strips of paper graded in their width, pasted on the edges of the pattern.

D

Only the simplest stresses have been dealt with in this Paper, and the castings have been chosen so that the strains may be easily explained, but the line of reasoning employed with modifications can be made applicable to all casting stresses and strains. For simplicity and ease of application only the individual parts of a casting, as almost separate entities, have been considered. With a little study it will be found that this does not cover all that occurs in the formation of a strain; but to go more accurately into the causes would entail too lengthy a Paper.

Discussion.

THE CHAIRMAN said that they had listened to a very interesting and instructive Paper. Mr. Fraser did not mention the most popular illustration of the effects of strains, namely, the ordinary armed pulley. The distortion in that case, of course, was due to the uneven rate of cooling of the boss, the arm, and the rim. The defect could be corrected simply by trial. If it was found that the arm was not cooling at the same rate as the boss, means were taken to increase the rate. Most of the illustrations given by Mr. Fraser suggested bad design,, and wherever one got such distortions they might be put down to bad design. He was sorry that Mr. Fraser had not spoken a little more strongly about that matter. Mr. Fraser had remarked that the design in some cases could not be altered because the question of economy came in. It used to be said that if a designer studied the foundry he spoiled his design. Another point was mentioned by Mr. Fraser as showing the cause of some of these strains. Most distortions were caused by an uneven rate of cooling between the parts. Another thing was that wherever one got an uneven rate of cooling one always got different structures in different parts. In some of the illustrations shown it would be found that the structure in the distorted edges was different from that of the other parts.

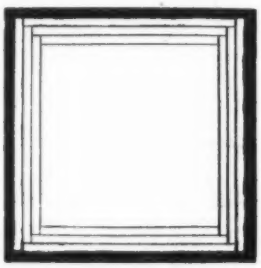


FIG. 17.

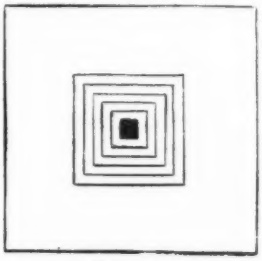


FIG. 18.

MR. F. H. HURREN said that he had known pulleys where the boss and the arms and the rim had come out of the mould in several pieces. There was one little point upon which he did not quite understand Mr. Fraser, and that was with regard to chilling on the inside of the box frame. In this case there were three thick sides and one thin one. Was the chill merely used as an experiment, or was it found to be more useful?

MR. FRASER: It was used as an experiment to gain some knowledge as to the effect of cooling on the direction of the bend.

MR. HURREN went on to say that he would have liked to hear more of the influence of design on stresses and strains—for instance, the effect of square corners as against round corners and the influence of fillets.

MR. ROBERTS asked, with regard to the case of split castings enclosed in a box, why, in order to prevent warping, was the box stood up on edge. This practice was common with box castings.

MR. PRICKETT asked Mr. Fraser whether he did not think that by using a different grade of metal a great many of the strains he had described could be avoided. He himself had known pulleys 12 ins. and 6 ins. thick with the arms cast successfully in good-grade metal. They had some of the trouble with pulleys described by Mr. Fraser, but had overcome it by using a better grade of metal, and the trouble only recurred when they departed from this practice—for instance, when a little ordinary metal was used to make up the charge.

MR. SHAXBY said that he had experienced a similar trouble with pulleys, but had got over it by using hematite.

THE CHAIRMAN said that the remarks of the last two speakers were quite correct. In his foundry they used four different mixtures. They had what was known as pulley iron for pulleys and hand wheels, then they had light machine iron for small parts, and heavy iron for heavy parts, and a very hard mixture suitable for lathe beds. It was quite right to use different mixtures for different classes of work. With regard to influence of design upon strain, he would take the design of the ordinary moulding box. When the corner was square both inside and outside, the box generally broke through at a very short distance from the angle; whilst if the corner section was round there was no breakage. The reason for this was that the cooling curves were always at right angles to the surface, and thus, with a square corner, they got the weak spot at the point he had indicated.

MR. FRASER, replying to the discussion, said that the turning of boxes on edge did help a little in bending, but only a very little. He had used that method, but he had never found much advantage from it. It was used very considerably in making plate patterns of uncommon contour which had to be kept straight. The moulder could strip the sand from that plate in different parts of the casting, and so make the plate bend in any direction he chose, according to the time at which he stripped the sand; or he could cause a bend by turning the box up with the plate casting in it and stripping the sand from different parts at special times. By this means one could make the plate bend in any direction or keep straight, but he did not think the turning of the box made much difference if the plate were inclined to bend.

Economies in a Malleable-Iron Foundry.

Ideal working conditions, says Mr. A. F. Conant in "The Iron Age," have been provided in the annealing department of the Rhode Island Malleable Iron Works, Hills Grove, R. I., by constructing the building with an unusually high roof. The centre-line distance from floor to bottom of roof truss of 27 ft. 6 in., or to roof peak of 35 ft. 6 in., serves to provide for the flow of heat far above the heads of the workmen. The absence of debilitating temperatures near the floor acts to insure a maximum physical effort about the furnaces even during the heat of mid-day. This department, 94 x 153 ft., comprises the greater part of a brick and steel structure, 94 x 211 ft., housing in addition both the hard and soft tumbling equipment and the inspection department; it is also liberally provided with steel sash to give flood lighting and free ventilation.

The annealing furnaces comprise 8 units, 12 x 20 x 6½ ft. inside dimensions, annealing from 18 to 22 tons of castings a day. They are fired on the side with two fire boxes on each side. Charging is by a Foundry Equipment Company steam truck with a capacity of 3 tons. Three checks are kept on the temperature control: (1) Base metal couple employing a system with portable pyrometer which can be plugged in on the circuit at any of the furnaces (used whenever any irregular condition is indicated; (2) the graphical recorder located in the chemical and metallurgical laboratory; (3) the standard indicator mounted on the wall of the annealing room. All leads for these circuits are carried in pipe conduit. The absence of any loose wiring and the high roof together afforded the company favourable insurance rating. Fire doors are also employed to isolate the room. The output comprises principally pipe fittings, line materials for insulating work, wrench parts, castings for pipe cutters, automobile parts, agricultural implement parts, and general machinery castings.

Because of the small size of the castings routine heavy-handling work is limited principally to the loading and unloading of raw materials in the yard. All such work is accomplished with a locomotive crane carrying a 1-ton grab bucket. The cars of coal, coke and pig-iron are switched into position adjacent to their separate open stock piles and unloaded by the crane, from 200 tons of coal or 150 tons of coke being a day's work. Pig-iron is hand-loaded into the grab bucket at a rate of about 2 tons per hour.

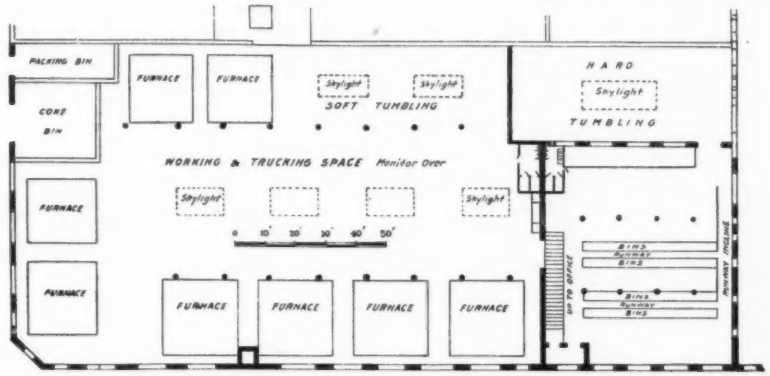


FIG. 1.—PLAN OF THE ANNEALING DEPARTMENT, SHOWING ARRANGEMENTS OF THE FURNACES.

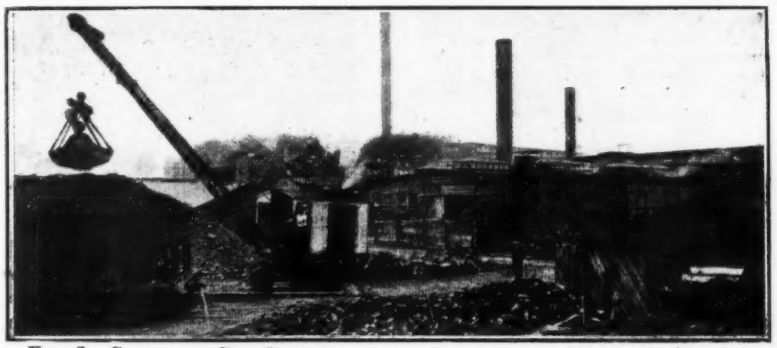


FIG. 2.—CRANE AND GRAB-BUCKET USED FOR LOADING AND UNLOADING MATERIALS.

Ample room is accorded for storage in the yard, and space for 3,500 tons of coal is provided to take care of a full barge load of 3,200 tons, which railroad tie-ups or embargoes at times make it necessary to handle. The coke stock pile will hold 1,000 tons, very nearly a year's supply. The capacity for pig-iron storage is 3,000 to 4,000 tons, and of scrap about 400 tons. To speed up unloading, an incline or ramp parallel to the yard siding and made of earth compacted between 18-in. concrete walls 14 ft. apart and about 120 ft. long, enables the craneman to bring the

crane about 5 ft. above the yard, so that he can watch the contents of the cars while unloading.

Great economy has been effected by concreting the entire yard to a depth of 6 or 8 in., except beneath the stock piles. The low-cost operation of the locomotive crane, motor trucks and the gasoline tractor which hauls materials from stock into the foundries on narrow-gauge tracks, is largely due to this concreting. As a result the yard gang has been reduced in three years from 25 or 30 men on full shift to 5 to 8 men who finish yard work about 3.30 p.m., and put in the remaining 1½ hour shifting weights in the foundry for the moulders.

At one side of the yard is located a frame building 15 x 215 ft., two stories, for the storage of moulding sand, sand-blast sand, fire-clay, furnace lining, fire-brick, lumber, core and machine oils and miscellaneous supplies. It is served by a special railroad siding, which allows for unloading several cars at one time. These materials are customarily unloaded by shovel or by hand, and reloaded in the same way on a 5-ton motor truck which does all the miscellaneous heavy yard hauling.

Core sand supply is derived from the company's own bank about 1 mile from the plant, to which it is transported by truck and dumped directly into a storage cellar at one end of the core department. Before freezing weather sets in about five months' supply is brought in, enough to hold over the winter, and in this way the nuisance of frozen core sand is done away with. A motor-driven chain bucket conveyor elevates the sand to the mixer.

The small size of most of the castings calls for very fine core work, which has led the company to employ on work of this class girls and young women, because of their inherent quickness and dexterity. For this reason the core shop, a high-roofed wooden structure, 40 x 163 ft., is arranged informally in two departments, one side containing benches for the females, and the other for the men whose work is confined to the larger and heavier pieces. The centre of the room is occupied by racks for storage of baked cores. The benches range alongside the windows, which are continuous on both sides, giving free ventilation during the heat of the summer.

The core ovens are segregated in a separate room at the end of the building adjacent to the foundry, avoiding any uncomfortable temperatures in the core department, which in addition to the many windows is ventilated its entire length by a turret roof.

The main foundry building, 80 x 260 ft., of brick, has a level, solid floor of brick set on edge. This has been found effective in cutting down the amount of moulding sand and scrap used, the level floor permitting the practice of butting the moulds together with jackets removed, so reducing to a minimum the number of jackets needed.

The melt is made in a standard type air furnace of 17 tons capacity, which is charged through the furnace roof by lifting six bungs over the hearth. No cupola equipment is employed. The capacity of the daily melt is 35 tons. The daily cast per moulder varies from 150 lb. to 3,500 lb., averaging 450 lb.

Storage for bottom boards and jackets or flasks has been provided beside the foundry building, the stacking being arranged according to sizes, so as to facilitate the assembling of proper pieces, save time and prevent useless waste of lumber for building new parts that cannot be readily picked out of an unsorted assemblage.

The hard castings are cleaned in a battery of 10 tumblers and are then wheeled up an incline and dumped in bins in the inspection department adjacent to the annealing department.

The tumbling of the annealed castings is by a battery of 10 tumblers, one sand blast and one rattler, installed at one side of the annealing room, from which they are wheeled into the stockroom preparatory to requisition by the shipping department.

In the pickling room the company has adopted as standard for the body of wheelbarrows and the bottom of barrels construction of 1½-in. hard pine, their experience being that this outlasts the usual sheet metal type several times over.

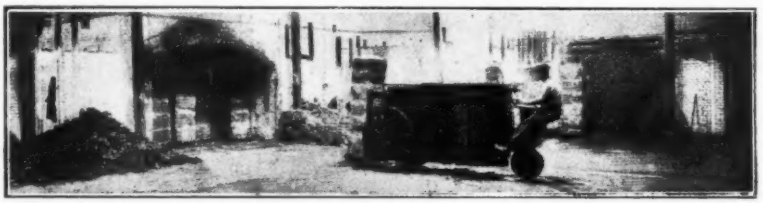


FIG 3.—CHARGING OVEN BY MEANS OF A 3-TON STEAM TRUCK.

The pattern shop, match room, carpenter shop and rigging department are contained in a frame building, 34 x 157 ft., to the rear of the core shop. Mechanical equipment includes two woodworking lathes, one 16-in. x 3 ft. Cisco metal-working lathe, one 16-in. x 5-ft. Reed-Prentice lathe, one No. I. Van Norman miller, one planer, two Reed-Prentice drill presses, one disc grinder, one wood buffer, and one bandsaw.

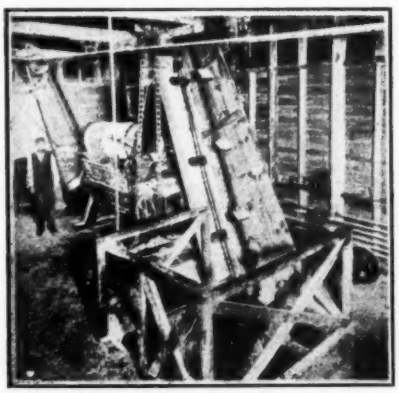


FIG. 4.—CORE-SAND PLANTS.

The ability to maintain a high standard of production is attributed to a large extent by the management to its policy of employing only non-union labour and paying a piece-work scale which nets industrious workers considerably more than union wages.

A careful daily record is kept of the percentages of broken and of bad castings, and a graphical plotting of these figures serves as an infallible warning to the superintendent of incipient trouble at some stage of production.

Impressions of a Sheffield Foundryman in America.

Mr. J. R. Hyde, of the Abbeydale Foundry, Woodseats, Sheffield, was a visitor to the American Foundrymen's Congress and Exhibition held at Philadelphia, U.S.A., in September. On December 3, 1919, in the Cutlers' Hall, Sheffield, he related his experiences and impressions, before the members of the Sheffield and District Branch of the Institute of British Foundrymen and the Sheffield Branch of the Junior Engineers.

Mr. Hyde said that while English manufacturers were always asked as to the quality of their articles to satisfy the specifications of the Admiralty, the War Office, or the many consulting engineers in London, everything in America seemed to turn on quantity. It seemed to him that somewhere between quality and quantity was what English founders should try to reach.

The Convention was representative of the industry in the States. Something between 300 and 360 members were present, and a number of other persons interested in engineering and metallurgy. In addition to the Congress Hall, there was an exhibition hall about a mile from the centre of the city, and in this were all kinds of moulding tackle.

The papers were distributed over various sessions and three rooms were used, so that three lectures were given simultaneously. There was a grey-iron session, a malleable-iron session, and a most interesting session was devoted to industrial relations, in reference to which there were reports considered from various committees. The papers were on widely divergent subjects. One of the most instructive, although non-debatable, was entitled "The Value of the Scrap Pile."* Until he heard that paper he was convinced that wasters (except a negligible 2 per cent) were unknown in America; but the author, Mr. Henry Traphagen, of the Toledo Steel Casting Co., applied candid criticism of it.

Mr. Hyde, continuing, said that mechanical sand handling and mixing machines were the latest labour-saving devices in American foundries, and three machines for mixing floor sand were shown at the Exhibition. The general principle of them was that they consisted of rotating blades at a height adjustable above the floor with frames and traction wheels. As concrete floors were now largely used, those machines could do the work very well and quickly, and he was greatly interested to find that one had been working in a Philadelphia foundry very satisfactorily for some months. Moulding machines are now mounted on wheels and pushed to the sand heaps to save carrying. The next things he observed were various power riddles. Some were worked by electricity and some by compressed air, and he found that a direct motor did the work with only one-quarter or one-sixth the power that compressed air took, and it was less liable to fall sick. Moulding machines were another feature of the Exhibition. They were of all sorts and conditions, but there was no new striking feature except an idea, which was to throw or propel sand in the mould with such force that it packed tight enough without ramming. He was afraid, however, that wear and tear would be a very serious factor in operating costs on this principle. Jolt ram machines were operated by cam and electric motors in preference to compressed air, for the same reason as sand riddles. Core oils and well-equipped core stoves were there in great numbers, and nearly all used splendidly-finished metal core boxes. There were also plenty of pneumatic tools and various electric furnaces and welding devices without any specially new feature. There was also a remarkable display of core boxes, the most remarkable of which were those used in the motor trade; and when he observed them, he could not help thinking that these were responsible for the mass production in the motor-car trade.

To get back to the original plan he had set out to observe, namely, how they managed their mass production. To him it seemed that it was done by cutting into short processes which were easily learned, and by making each of them mechanical as far as possible and independent of the carelessness of the operator. Detailed supervision was another great thing they observed. American foundrymen and especially the Association seemed to be more frank than we were in publishing what he would call essential information. They then gave a lot of information about cost, and though one could make allowances for enthusiasm, still by reasonable cross-examining, one could get at the workable truth. They cross-examined one another in a remarkable way, and learned how far the statements were to be relied upon.

The Exhibition was unique in showing the magnitude of the foundry industry in the States, the manufacturing system used in mass production, and the wear and tear on all machines which made improved models worth installing. He regretted to say that he had omitted to make inquiries about the life of machines that had been in constant service, but as the most of those machines were constructed lightly, the easiest way, no doubt, to repair a machine in America was to scrap it and buy another.

As a side issue he wished to say a few words on the constituent parts of American business. There was no doubt that American businesses were not in two component parts, Capital and Labour, as in England. There were three, far more clear and distinct than our two. They were capital, labour, and management, and the greatest of these and the section that ran American industry was management. In such a country, with its many openings to promotion and prosperity, a man with initiative soon left the ranks of labour and took a hand in the management, and with his savings and bonuses soon took an interest in capital.

The motor industry was one, which, being modern, showed the latest development in properly planned and executed mass production. For instance, the Chevrolet car was produced at the rate of 720 per day, the Buick car at 500 per day, the Dodge car at 400 per day, and the Ford car at 3,000 per day. He would ask them to contrast that with the negligible deliveries of English cars during the twelve months following the Armistice, and then as Britishers honestly ask themselves why?

* See December Issue.

There were several reasons, but one certainly was the co-operation of the works management in cutting out the "snags" which held up manufacture; and if the drawing office showed a part which was going to give trouble in keeping up to the schedule in the foundry, it was modified without any loss of dignity. All work, too, was planned ahead like a time-table, and the individuals composing the management were responsible for their section being up to time. Should a department prove a "lame duck" it was assisted by advice from other departments or an outside specialist was called in. The outside specialist thrived to a remarkable degree in American industry. In the foundry industry he was usually a practical man. In England we went for the outside theoretical man, but there, they got a good man who was competent to go to the sand heap and criticise the moulder. The outside specialist worked quite amicably with the works superintendent. They seemed to be a happy family.

Now, continued Mr. Hyde, the study of management cannot be complete without extending it to the labour questions that it is to handle. Labour in the States is almost invariably paid on the piece-work system or a bonus system, which definitely has for its object high production and suitable reward. This fits in with the American idea of each man making the best of himself and for himself, and if an average rate is fixed the better man physically or mentally is suitably rewarded. There is, however, no doubt that the cutting of operations into short items tends to simplify the requirements from each individual, and consequently the man who actually does the work in the foundries of America has not to have more than a quarter of the knowledge that our moulders possess in England. The results, however, as far as quantity production is concerned, are quite satisfactory, as the responsibility for the brains and the designing of the tackle are in the hands of capable men, and their tendency is to reduce everything to plain straightforward instructions, which are very often printed for the guidance of the worker. Thus sand mixing is done mechanically and standardised as far as possible, and large bins for the storage of standard sands are the general rule. After the mould has left the moulding machine it is generally cored and then cast under almost standard conditions, and owing to this fact some internal troubles, due to limitations of one man endeavouring to carry his job right through are eliminated.

In one of the foundries visited they were actually making castings very similar to those we are interested in in our foundry, and I figured it out that in the day of nine hours just over twice the number of moulds were put down per man, for which he received $5 or 24s. In translating this into plain English, the actual moulding cost in the American foundry is only 60 per cent. of what it costs us in Sheffield, and it is a fact that although some of the remaining 40 per cent. may be swallowed up in interest on the labour-saving devices employed, still there is no doubt that with the high wages and higher production the American foundry is producing castings cheaper than we are. The selling price of automobile castings compared with the figures in this country further bears this out, and to-day's prices of many engineering items, locomotives, stationary boilers and automobiles, fully confirm this. All these things are cheaper to buy in America than here.

Now, as a progressive Society, we must take steps to investigate the conditions in our works which can be reasonably improved. The installation of labour-saving machinery, although welcomed theoretically, must be genuine; as by cutting out the laborious muscular work, our workshop life will be made tolerable, although somewhat monotonous, by the standardisation of processes. We can remember the day when horses were considered quite satisfactory for drawing tramcars, but no one would suggest that we continue to use horses if we want quick transit. And I am sure some of our old ideas on manufacture and wages will bear modernising without detriment to our dignity, but with tremendous gain to our efficiency. We can then use our extra hours of leisure to indulge in recreations which will tend to make life worth living. The old motto "work while at work, and play while at play" will form a sound basis for happy industrial living.

I have little more to say, but when one hears our country criticised by business men who have been educated in keen efficiency, we cannot help making an effort to put our house in order and learn to rely on ourselves, and not on the Government. We are told that now is the day of specialisation and mass production, and I must say that many who write in the Press on this subject show little knowledge of their tremendous meaning. If our discussion turns on mass production, please give thought to the enormous detail work which must be carried out with absolute faithfulness if a factory is to give the regular output it is designed for.

Discussion.

DR. HATFIELD said Mr. Hyde was a Sheffield manufacturer, and incidentally an Associate of the Sheffield University, so that in going to America he went as a qualified man capable of discriminating, and any impressions which he had formed might be taken as perfectly reliable. Regarding the American Bureau of Standards, which was the National Physical Laboratory in America, it was not exaggerating to say that the Bureau of Standards when he was in America was receiving ten times as much money for its support as the National Physical Laboratory did here. Further, it took a real definite and effective part in the industrial organisation of America. It was the ultimate Court of Appeal for anything that concerned the properties of metals physically or mechanically, and he would like to see the English National Physical Laboratory take up the work to the same extent as the Bureau of Standards in America. The British Government had now taken over the National Physical Laboratory, and he hoped it would be supplied with sufficient funds and encouraged in its work along the lines of the American Institute. With regard to mass production, it seemed to him it was all reckoned up in one word, "equipment." He thought if their technical experts were going to make a success of mass production they should give more attention to the equipment and mechanical side of the problem. Otherwise they would fall short.

MR. DARLEY said, with regard to mass production, there was no doubt that it had to come, otherwise they would have to take a back seat in England. He agreed that equipment was the secret of mass production. In the automobile industry, which was practically a new industry, it

was easily applied. It could be applied better there than, say, in Sheffield's steel industry, which was an old one, and in most of the businesses they were handicapped for the want of room. Still, there was room for improvement. With regard to the moulding machines, he would like to ask Mr. Hyde if they were worked by skilled or unskilled labour, and also whether any women were employed in the working of them.

Mr. Dalton remarked that the American business man, when he set about building a factory or foundry, did it from a different point of view from what we did. In the first place, it was probably more a financial man or one of those successful superintendents of whom Mr. Hyde had spoken, who went into it. That man designed the foundry for a certain specific purpose, and he realised that to make a certain percentage on his money it should be so designed and equipped. He did not allow himself to be tied to one place. If a place did not suit he moved elsewhere. It was quite a feature of American industry that the works were on the outside of the cities, so that they had room to develop as the occasion demanded. As for the quality of the work done in America, it was in some respects equal to ours; and when they heard of the large percentages of failures he thought it was due in America to the large output. In England the failures or wasters occurred chiefly during rush times.

Mr. Firth said he would like to ask if they were in the habit of doing large castings in America—say, castings up to 20 tons or upwards—on the piece-work basis, and if so how was it arranged with the men working on the job.

Mr. Bradley requested more detailed information on the question of supervision in the foundries. How many men had a superintendent over them? He would also like to ask about the quality of the work of mass production.

Mr. Halls asked if the Americans had yet adopted to any large degree the rock-over or turn-over to any description of machines? At present the British moulding machine carried up to four tons. He personally advocated the electrically-driven jarring machine, though there was difficulty on account of the gearing down of the motors. In a green-sand shop 20 or 30 jars had the disadvantage of getting the moulds too hard. He did not think equipment was the secret of mass production. It might have a great deal to do with it, but he thought the system of supervision had more to do with it. He had been in moulding shops where they used machines, and yet he found men who were able to do more by hand, simply because there was no system of supervision in the use of the boxes. He thought the foundry foreman of the present day had too much to look after. If there was a man for moulding machines he should devote his time to them. He thought the work should be more divided up, and have one man for each department.

Mr. Browne asked what precisely was a superintendent? Was he a foreman; because he had never heard the term foreman used in connection with an American shop. Was he the experimental moulder? Another point which should be remembered when contrasting American and British castings was, as Dr. Boswell had told them, that most of the American shops made their castings for their own use and finished their own work right through. In this country shops were making castings for outsiders. In that way what would pass in America as quite good for the job would not be taken in England.

Capt. Rundle said they could not have mass production until they had agreement between capital and labour on equipment. He had no doubt the hints on the scrap pile would be of interest to all foundrymen, because he had often been struck with the practice that obtained of making a thing first to see how it should be done, and the next time perhaps getting a good one. If some such systematical method of collecting information as that suggested were adopted, and information properly tabulated and recorded, a lot of time would be saved.

Mr. Shaw said he agreed with a lot Mr. Hyde had said. He had been in America, and he knew perfectly well the trend of their work. He did not agree, however, as to the number of failures. The chief point was mass production. The first thing was that the job was timed, and there was a definite understanding between the superintendent or foreman and the man on the job. In that way they got how long a job should take, and were able to fix the piece-rate. If a new job went into the shop it was taken to the floor or the machine, and the times for each part of that job were taken, and there was an agreement between the Shop Committee and the Superintendent and the management that such times were fair. There was another point. Our men generally object to being told how to do a job. The American had a card with instructions. The work was done on the Taylor system, and it was done with the least possible movements. For the information of a gentleman who asked about ingot moulds, he would say they made ingot moulds in America by the thousand on the machine. It was not true to say that all men in America were on piece-work. But there was often a bonus and an understanding made with the men for extra work, because often a job was "one-off" and a piece-rate could not be fixed. There was one point of difference between the English and the American Associations, and that was the latter asked for and were given information by the foundries. Of course, one need not believe all the information that was given.

Commander Jackson, with reference to the experimental moulder, asked if piece rate was fixed from data obtained from such moulder. To his mind there was no use in decrying American castings. They were producing the goods, and that was the thing that mattered most in those days.

Mr. Cope asked Mr. Hyde whether the patterns used were wood patterns or cast iron, and were any particular provisions made from the different kinds of running.

Mr. Dawson asked if Mr. Hyde could give them any information or the hygienic side of the American foundries. He believed the conditions obtaining in foundries here were as good as in America, and the Englishman could always beat the American at his work. That was fully verified by a statement made by Mr. Backert, of the American Foundrymen's Association, when he was over here. His idea was that we were in front of America, and that things were turned out much better and quicker here. If what Mr. Hyde said was correct, then all the foundries were obsolete and out of date, and for that the employers were to blame. His opinion was that they were all too

much afraid to speak: there was too much secrecy, and he would like to see the facts given.

MR. TAIT asked for information on what America was doing in regard to moulding for shipbuilding and marine purposes. He had seen a 17-ft. 6-in. propellor moulded in Newcastle in four days. It weighed nine tons, and he would like to ask if Mr. Hyde had seen anything done to equal that.

MR. HYDE, in the course of his reply, said the foundries in New York and Philadelphia and other places on the near coast were somewhat like Sheffield, for the reason that they had been built about 100 years ago, and consequently in many cases suffered from the same disadvantages. In the other places on a future visit he would no doubt be able to see more of the light castings and repetition work, in which he was interested. With regard to the Bureau of Standards, he believed it made up in some degree for the deficiency in Universities in America. There they had no Universities like Sheffield, Manchester, and Liverpool, and other places in this country, which were such a help to the industry.

DR. HATFIELD, intervening, said he believed that the Universities were far more numerous in America than here, and, further, he ventured to suggest that they were receiving ten times the financial assistance from the State than the English Universities were. He was of the opinion that it was rather due to the fact that they had such a widespread University system in America that such a body as the Bureau of Standards was in existence.

MR. HYDE, continuing, said that some of the machines he had seen handled 200 tons of sand daily; they cost about £8,200, and that was given as the minimum quantity to be handled on a commercial basis. The moulding machines in America were operated by unskilled labour, but a man who operated one was given foundry help. If that help could not speak English, the work he was supposed to do was printed on a card in his language which he could easily understand. It was Henry Ford, of course, who had that thing reduced to a nicety. Every man was an expert in his own line in that factory. A man was trained for one job, and he became quite expert at that. He had seen no women employed in any of the foundries, but they were engaged in the core shops. Another thing in American business was that things were constantly being planned ahead. They had experts for that. Relative to other questions, he had not seen any large castings. The bonus system was in every foundry, as far as he could see. A man was not content to work for the day-work rate. On the subject of supervision, the idea was to have a man in charge of a limited area in the shop. He was not called from one end of the shop to the other. A man might be looking after one group of moulding machines, and he stuck at that. By sub-dividing the work there was one man supervising about 20 unskilled men.

As to the power for driving the moulding machines, he found that a good many of them were electrically driven. For a few jars they were not a success, and he thought the pneumatic machine for steel was to be preferred. With regard to the quality of castings, he should say that he had seen some of the best small castings in his life in Philadelphia, being produced by the thousand in a shop where they used the electrically-driven sand-mixing machines. One man was making 140 moulds per day. He (Mr. Hyde) had not taken the trouble to measure the size of the boxes in that case, but the sand was brought down by a chute and the man did not move his foot once from starting to ram the mould. In a good many cases in England there was a lot of unnecessary movements. High production in America was due to a large extent to a system of cutting out unnecessary movements. Another thing he had noticed was that there was no gossip going on in any of these shops. With regard to the finish of castings, he did not see any that was better than our own. Where they were worse was when there was insufficient attention paid to patterns; but, generally speaking, the patterns were not knocked about or allowed to get damaged.

The rate-fixer was an important man in the engineering and foundry shops in America. He was not quite so uncomfortable as the rate-fixer in Sheffield, because he seemed to strike the happy medium, satisfying the superinetndent and the worker. Firms were not at all concerned as to what wages a man took home every week if he was on a standard job. Moulders on large loam jobs like those employed in the Baldwin Loco. Works got two-and-a-half times the ordinary day-work rate. The experimental moulder was an entirely different man to the rate-fixer. He had quite different qualifications, and if they required different qualifications they took the trouble to search out the right man for the right job. With regard to patterns, white metal patterns were very largely used. No doubt they cost something, but when there was a great deal of work to be turned out they paid in the long run. With regard to hygiene, there was no doubt that in nearly all the foundries the most up-to-date sanitary devices were provided, where men could wash and clean themselves after work. That was absolutely necessary in a place like America, where one got the extremes of climate. Whilst he was there the thermometer never registered less than 70 deg. in the shade, and men had to work in just a light bit of singlet. There was another factor. If a man found a thing did not do, he did not content himself with merely trying to mend matters: he scrapped the lot. Here, if a manufacturer was convinced that a machine could do a certain thing, he did not mind scrapping an old one and substituting something better, but he had never yet seen an English manufacturer who was prepared to scrap a whole plant. Another point that struck him was the necessity for building works near a railway siding. In Sheffield they built their works anywhere, but in America that would not be tolerated. The railway there was in everywhere for carrying heavy work.

The whole thing turned on production. With regard to the question of big marine work and what was being done at Newcastle, he quite appreciated the question, and he hoped that England would still continue to lead in that respect. Americans had begun to build ships. At present they were only small in size, but he anticipated in the near future they would develop that side of their business with keenness. With regard to pneumatic rammers, they were remarkably delicate things to handle, and a grain of sand would throw the whole thing out of gear. In conclusion, Mr. Hyde said his experience had been an eye-opener.

Institution of British Foundrymen.

NEWCASTLE BRANCH.

Education of the Ironfounder.

By Professor Louis.

Before the Newcastle Branch, on November 29, 1919, Professor Louis, of the Armstrong College, gave an address on "The Education of the Iron Founder," in the course of which he said :—

Iron founding is so complex an industry that it is no easy matter to decide what qualifications are needed in order to attain to success therein, and still less to what extent these qualifications can be developed by education. I have long held, and hold more strongly to-day than ever, that whilst it is the duty of the State to educate the man, it is the duty of the industry to educate the technologist. No industry has the right to ask the State to provide those educational opportunities which have for their object the improvement of the technologist as distinct from the development of the individual.

...Coming more particularly to the education of the iron founder, each branch of the industry requires individual treatment. I am bound to admit that the moulder needs little or no technical training individual treatment. I am bound to admit that the moulder needs little or no technical training beyong what he gets in the foundry itself, and that he has got to learn his work on the floor of the moulding shop. The skilled moulder takes high rank amongst modern craftsmen, and the manual dexterity that he needs can only be acquired by constant practice. Education will not help him greatly, but any training that develops co-ordination between hand and eye must be of use to the young apprentice.

Probably no better education can be devised for the purpose than that to be obtained in Art classes. A certain amount of geometrical drawing would be of great use to him as training him in accuracy of method and work. Freehand drawing should be of special value, but this must be taught in such a way as to give him a free, bold style rather than minute delicacy of finish. A good deal of the work should take the form of blackboard drawing with the above object.

Finally, he should, if possible, be taught modelling and working in clay or some similar material; when a student has reached a certain stage in drawing he has necessarily to adopt conventional methods of working which appeal mainly to his powers of idealisation, because he has then to represent solid objects on a plane surface, and this imparts a certain amount of unreality to advanced work. Modelling is free from this objection, for the student learns thereby how to reproduce the actual form of the solid objects set before him

It will be understood that I do not suggest that any of these subjects should be taught as they would be to an art student desirous of becoming an artist. The moulder requires only the more elementary portions of each subject, and the definite educative object of the training, that of teaching hand and eye to work in unison and of producing a correct judgment and appreciation of form and line, must always be kept steadily before the teacher.

The moulder need not necessarily know much about the quality and composition of the metal that is supplied to him, and as regards the texture and temper of his moulding sand, a very short experience suffices to teach him all that he needs to know. The moulder is one of the few craftsmen whom modern industrial methods have left largely untouched, and in some aspects of his work he comes very near to realising the ideals of the artist; indeed, he is an artist as far as the technique of his work is concernd, though it must be conceded that no demand is made on the higher qualities, imaginative and creative, of the artist proper.

The first-class pattern-maker must not be only a highly-skilled tradesman, but must have sufficient general engineering knowledge to read carefully even an intricate drawing; he must have sufficient knowledge of the material of which the castings are to be made to enable him to make due allowance for shrinkage and to teach him how its crystallisation will affect the strength of the casting, and, finally, he requires a very wide experience in his own craft to teach him how a pattern should be built up, how and where cores should be introduced and all the other technical minutiæ that can only be learnt in the school of experience.

Here, again, nothing can take the place of a proper apprenticeship. The same hand and eye training as has been suggested for the moulder would probably be found of the most use, in the first place for the pattern-maker; the latter must, however, do much more geometrical drawing and have a thorough training in mechanical drawing. It is almost a truism to say that no one can really understand thoroughly the drawing of a piece of machinery unless he is fully qualified to make the drawing himself. In addition, quite a considerable amount of training in science, at any rate in elementary science, is required.

Physics and chemistry, especially the former, are the foundations on which a knowledge of the properties of metals is based, and these are no doubt the best subjects for study; the principles of mechanics, a certain amount of general engineering and the elementary principles of metallurgy would probably complete the educational training of the pattern-maker apart from his training as a craftsman, which he can only get through his regular apprenticeship. This means, in fact, that he must necessarily serve his time in the ordinary way in the pattern shop, the school teaching to be obtained concurrently in evening schools. No doubt it would be sound policy for pattern-makers' apprentices to give up one or two afternoons a week to the teaching already indicated; the educational development thus attained would probably far more than compensate the young apprentice for the sumewhat shorter time spent in the shop, and I venture to suggest that employers would be well advised if they adopted such a method of education.

Coming lastly to the foundry manager, his education must be on entirely different lines, because the demands made on him are of an entirely different character. It is not necessary for him to have any manual dexterity or skill in craftsmanship; he must, of course, understand the work of the moulder and of the pattern-maker, but there is no need that he should be able to do it himself; indeed, it may fairly be said that it would be sheer waste of time for him to cultivate such skill, as he is never likely to require it, and if he had at any time possessed it, he would lose it through want of the continual practice that is needed to keep up such qualities to their highest pitch.

His technical education may, therefore, begin at once by a study of science.

Again, beginning with physics and chemistry, and, of course, a sufficient amount of mathematics to enable him to understand these sciences in their more modern developments, he must receive a thorough training in the principles of engineering. Foundry work is a development of metallurgy, and metallurgy in its turn forms a section of applied chemistry, so that the iron founder must of necessity be both chemist and engineer, and his training must cover both these subjects, and therefore includes an exceedingly wide educational range. This means that his education must follow quite closely that prescribed for an ordinary University degree in Applied Science, and must commence with mathematics, mechanics, physics and chemistry in the first place, all these subjects being taken up to a fairly high standard.

He is then prepared to commence to specialise, and he will have to study those more advanced branches of science that bear more particularly upon his future work, such as physical chemistry, strength of metals, theory of structures, etc. Finally, he will have to study engineering and metallurgy, the latter being looked upon as his chief subject.

This, in brief outline, covers the list of scientific and technical subjects that form the basis of the iron-founder's work. I need hardly say that I use the word "metallurgy" in the broadest possible sense, so as to include the theory of alloys, metallography, heat-treatment, chemistry of metals, utilisation of fuel, pyrometry, refractory materials and the assay and analysis of the various metals and materials used in the foundry. This may seem a sufficiently formidable list, but I submit that every item in it is necessary for the complete education of the iron-founder.

In addition to the scientific subjects, he ought also to study a certain number of economic subjects, such as economics, accountancy, elements of commercial law, etc. Such a course would occupy four years at college, and, in my opinion, cannot well be done in less. Some will perhaps hold that I am asking too much of the iron-founder, and I very often hear some remarks such as this: "My father was an iron-founder and a very successful one in every respect, and made plenty of money, although he had never heard of a thermal equilibrium diagram." Such a statement is perfectly true, and no doubt the old-style iron-founder did admirable work and brought the industry up to a remarkably high standard, with no other guidance than experience and common sense, though we never know how many failures had to be registered before success was achieved.

The world has, however, not been standing still, and the demands upon the iron-founder are far more severe and specifications stricter than they were half a century ago. In this country we have to compete with other nations who have been placing their industries on a strictly scientific basis, and if we want to hold our own in the fierce industrial struggle that is even now at our gates, we must enter the arena no worse equipped for the fray than our competitors. I have no hesitation in saying that iron-foundry work in this country is on far too empirical a basis and that the iron-founder has never availed himself properly of the resources of modern science, and still appears to appreciate insufficiently their commercial value. The proportion of large iron-foundries in this country that have not even got a chemical laboratory at their disposal, is still lamentably large. My own experiences of the work has proved definitely to my own satisfaction that chemical control even itself will reduce enormously the proportion of wasters in the foundry, and I need not add that this is one of the main elements of commercial success in the iron-founder's business. I am not advocating the employment of scientific methods on the grounds of abstract science, but purely on the basis that it is a payable commercial proposition. The best proof of its soundness lies in the fact that iron-founders who have once introduced scientific methods will never be found willing to give them up and return to the old principles of rule-of-thumb.

Let me, however, add distinctly that I do not for one moment imagine that any amount of college training will by itself make an iron-founder. I am only advocating it as the best foundation upon which a sound knowledge of the industry can be built up. The college work is only the preparation; the real work of the iron-founder can only be learnt in the foundry itself. My theory is simply that the men who has learnt the scientific principles of his industry in college and has afterwards seen how these can be applied in practice, is far better equipped to meet the emergencies that arise constantly in the daily routine than the man who does not understand the reason underlying his operations and has only experience to guide him.

The last point that I need discuss here is the question, Where on the North-East Coast can the complete Metallurgical Education that I have advocated be obtained? It is with very profound regret that I have to admit that the only truthful answer is "Nowhere." Speaking with particular reference to the college with which I am connected, we are in the position of being able to teach quite satisfactorily all the subjects that I have mentioned, except the one which is most important in the present connection, namely, metallurgy, and for this we are, I regret to say, quite unequipped. The metallurgists in this district never appear to have realised that they owe a debt to themselves and their industry no less than to its leading educational institution, and have never made the slightest effort to equip a Metallurgical Department worthy of their important industry. Surely they have not been waiting all these years for others to do for them what they ought to do for themsleves? If this attitude is persisted in, I am afraid they will wait until it is too late. The deficiency under which we are labouring is both in the matter of teachers and of appliances. As long as the teaching profession is as badly paid as it is to-day, it is hopeless to expect to attract into it a fair proportion of the brains of the nation, and nowhere are they more badly needed, in the interests of the nation itself.

Let me quote a case in point. A short time ago I was told of a leading hand in a smith's shop on the Tyne who gave as his reason for seeking another job that he could no longer make £20 a week at it. On the same day I saw an advertisement for a lecturer in metallurgy, the salary offered being £250 per annum.

Now, I do not grudge the blacksmith his £1,000 a year. I know how much skill, intelligence and energy and skill are required by such a man, and I know how much his work takes out of him physically; but I maintain that the man who is supposed

to be and is capable of teaching him the principles underlying his work is worth more than a quarter of his wages. As long as such vast disparity in payment persists, you cannot expect young men deliberately to elect to devote themselves to teaching, if they have the capacity for doing more remunerative work.

Next to the need for teachers for the highest class comes the need for a properly built and fully equipped metallurgical laboratory in the proper sense of the word. This must not only be an assay laboratory; it must be equipped with all modern metallographic and pyrometric appliances, must include furnaces for melting and appliances for working metals. It should include a plant for making castings (of course, only of small weight) and a modern testing laboratory. With a properly built and equipped laboratory, properly staffed, not only could the teaching of metallurgy be carried out satisfactorily, but it would also serve as a centre of research for the industry of the entire district, where problems beyond the capacity of the individual foundry or foundry chemist could be attacked with some reasonable prospect of success.

Every iron founder knows only too well that such problems are of every-day occurrence. How often does it happen in a foundry that a certain line of castings which have perhaps been made successfully for a considerable time, suddenly go wrong for no apparent reason, and only after a time, occupied in groping more or less in the dark, are they got right again, generally without the real cause of the trouble being ascertained, leaving the founder with the uneasy consciousness that the same thing may happen again at any time and find him just as helpless. I need not add that such occurrences represent money losses which often run into important figures, and that as a business proposition it is worth while establishing such an institution as I am suggesting. You are all prepared to insure against fire; is it not worth while paying a premium for insurance against ignorance which is at least as dangerous?

SCOTTISH BRANCH.

Corrosion of Cast Iron.

At a meeting of the Scottish Branch on December 6, 1919, a lecture was delivered by Professor Desch, Ph.D., D.Sc., on the "Resistance of Cast Iron to Corrosion." Mr. William Bell (Branch President) occupied the chair.

The lecturer at the outset stated that iron would be an ideal metal were it not subject to corrosion. By reason of the fact that cast iron was not a homogeneous substance it was not possible to make it non-corrosive. However, it was quite practicable to influence its resistance to corrosion by modifying the structure of the metal.

Prof. Desch then made some reference to the various actions which influenced corrosion, such as air, water, acids and the actions communicated by leakages from electric currents. Cast iron will not corrode in dry air, neither will it rust in pure water. It is difficult, however, to obtain water that does not contain some carbonic acid. When the surface of iron is influenced by the action of carbonic acid, either in water or air, corrosion results. When any moisture gets deposited on the surface of iron, oxidation takes place. The action appears to be that first a ferrous carbonate is formed; this is then oxidised by the oxygen of the air with the liberation of carbonic acid. Carbonic acid attacks a further quantity of iron, and so the reaction proceeds. A very small quantity of carbonic acid will cause iron to rust very rapidly.

Iron is not the only metal which is subject to the influence of corrosion. The corrosion of iron, however, differs from that of other metals, such as aluminium, lead and zinc, in that the oxide which is formed on iron is readily removed and a new surface is exposed. On the other hand, when aluminium, lead and zinc oxidise, the film of oxide which is formed is comparatively tough, and not readily removed, and protects these metals from further attack.

Common brass corrodes when in contact with sea water, but if 1 per cent. of tin be added to the alloy, the corrosive effect is reduced considerably. The small addition of tin does not prevent corrosion taking place; it only alters its effect. When the tin is introduced the corrosion forms a protective substance on the surface of the metal like an enamel, and prevents further corrosion taking place. It is by reason of this fact that the Admiralty specify their brass with 1 per cent. of tin.

The resistance of metals to atmospheric corrosion cannot be determined in any way other than subjecting it to the influence of the air. The behaviour of a metal under the influence of sulphuric acid is no guide to the resistance it will set up when subjected to the actual conditions resulting from its exposure to the atmosphere. The only way to find whether certain constituents increase or decrease the rates of corrosion is to expose the material to the actual conditions under which it is to be used.

The corrosion of cast iron is much affected by the nature of the skin on the casting. Castings which have not been machined resist corrosion much better than those which have the original skin of the casting broken. The skin which forms on the outside of iron when cast consists of a thin layer of ferro-silicon and has a powerful corrosion-resisting property. Many processes have been tried, with more or less success, to produce a corrosion-resisting coating on the outside of iron castings. The disadvantages of most of these processes is that once the protective skin is broken corrosion proceeds very rapidly. White cast iron resists atmospheric and chemical corrosion better than grey iron, and in the case of grey iron the smaller the percentage and size of the graphite the better. Cast iron to withstand corrosion must have a close structure, the graphite content of the iron must also be reduced to the lowest possible point, because from investigations which have been made it has been found that the flakes of graphite intervening between the crystals of the metal present entrances or paths for corrosion right through the casting. Some of the irons advertised as non-corrosive contain as low as 1 per cent. of carbon.

Silicon is another constituent which has an important influence on the resistance of cast iron to corrosion. Although it is advisable for ordinary white or grey iron to keep the silicon as low as possible, silicon when present in high percentages has a totally different effect. It is found that iron with 10 to 15 per cent. silicon has remarkable properties in resisting acids. The earlier alloys of this type had over 1 per cent. carbon, and were brittle and almost impossible to machine. More recently, however, improvements have been made which allow the castings to be machined without serious difficulty. The carbon percentage is now

generally lower than 1 per cent. Although metallic manganese in itself is more readily attacked by acids than iron, it is generally found that an increased manganese content in cast iron improves its resistance to corrosion.

A form of corrosion met with in underground pipes which have been placed in moist earth and possibly subjected to stray electric currents is that known as graphitisation. From the micro-examinations of specimens which have been thus attacked was greatly appreciated. An interesting discussion had altered, the graphite and phosphide remained unchanged.

The lecture was illustrated by lantern views, and was greatly appreciated. An interesting discussion followed, and the meeting terminated by a vote of thanks to the lecturer.

SCOTTISH BRANCH.

Foundry Costing.

At a meeting of the Scottish Branch on January 10 (Mr. William Bell, Branch-President, occupying the chair) Mr. A. Fraser lectured on "Foundry Costing."

Mr. Fraser explained that one of the reasons for selecting foundry costing as the subject for discussion was because of the fact that hitherto the papers presented to the Association had been more or less of a practical nature; his idea therefore was to introduce a subject having some reference to the commercial side of foundry work. The system which he proposed to discuss might not be applicable to every class of work, but it proved suitable for his particular branch of trade, namely, the founding of engineering costings.

Mr. Fraser then exhibited one of his cost slips and stated that it would form the text of his subject.

Cost Slip.

	£	s	d.	£	s.	d.
Iron at current cost, per cwt. ..						
Plus loss in melting, allow %						
Other raw materials—						
Greensand, per cwt.						
Drysand, ,, ...						
Loam, ,, ...						
Wages cost: Moulders, including dressing and labour—						
Hours ( ). Per Hour ( )						
Pattern making						
Wood, etc., at cost						
Plant (if any), special						
Oncost, covering salaries .. .. / General exp'nses / Depreciation, interest .. / National Insurance .. .. / Renewals and repairs .. — % of total wage cost or % on total cost. — Or mean of these two.						
Carriage, freight or cartage, at actual cost						
Insurance against bad castings on sum of foregoing ..... %						
Discount (if any) on same ..... %						
Credit beyond one M/O (if any) %						
Agents' commission (if any) ..						
Plus profit						
Selling price						

Costing, he continued, was, like many other subjects, associated with foundry work, that no hard and fast laws can be laid down which would suit every class of work; foundry work was specialised, and seldom was it the case that two foundries did exactly the same class of work. Taking, for example, a firm doing a trade in light castings, the costing system would require to be entirely different from that for a firm dealing in heavy engineering castings, because in the light castings trade there had been established the system of payment by results, in which circumstance it might be better to price each job on an independent basis.

In the lecturer's practice he had found it preferable to base his prices on work which had already been executed, and in view of this he believed in keeping an accurate record of the cost of every job passing through the works. In this way his manager and works foreman were relieved from saying definitely the exact amount of time which would be required for each particular job. He had found, and he believed it was the experience of others, when the works foremen were asked to estimate the time for each job there was an inclination to keep on the safe side and over-estimate the work.

Before he established his present system of costing he had an accurate record of the cost of every job before him which had been exacted by his firm for a period of several years. He had also records taken for periods of 12 months of the amount of metal melted and the total weight of the metal in the finished castings during that time; from these records he determined his percentage of metal loss. From the same records he could determine his cupola charges and ascertain the cost per ton of metal melted.

He based his charges from unskilled labour and dressing as a percentage on the cost of moulding. Under "Pattern-making" certain charges had to be allocated even when the patterns were supplied to the foundry. Special plant was another item which had to be considered in the price of a casting.

On-cost—covering salaries, general expenses, depreciation, interest, national insurance, renewals and repairs—had also to be considered. A percentage covering on-cost could be arrived at by lumping the foregoing charges from past balance sheets, or by estimation and based on the relation which such expenses bore to the total wage cost or the total cost or a mean of these two.

Insurance against bad castings was another item which had to be considered because bad castings would arise even in the best equipped foundries. The percentage of loss on some castings was very much higher than on others, and owing to that particular circumstance it lay with the founder, in arriving at his percentage, to either divide his castings into groups with varying loss percentages or fix a sum covering all castings. This percentage should be on the total cost of the casting.

When working out the cost of castings it would be found that castings in greensand were the lowest, drysand coming next, and castings made in loam the most costly.

The last item to be added was profit, which should be reasonable and equitable if this country were to maintain its position in the world's trade.

An interesting discussion followed, and Mr. Fraser was accorded a hearty vote of thanks for his lecture.

The Case-Hardening of Steel.

By F. C. A. Lantsberry, M.Sc., F.I.C.*

The process of case-hardening is one of the arts practised by the ancients, which has not been lost during the lapse of time. It is probably as old as steel itself, and it is known that even before the ninth century such tools as files were made by cutting teeth in bars of wrought iron, heating up in mixtures of leather, horn, salt, and other weird materials, followed by quenching. The celebrated French metallurgist, Reaumur, was the first to make a study of the scientific principles underlying the conversion of iron into steel, but the progress of his work was seriously hampered by the unfortunate notions on the composition of matter which persisted in those days. Reaumur's name is usually associated with the production of malleable castings, and it is very interesting to note that he was led to the study of the conversion of hard cast iron into malleable iron as a result of his earlier work on the case-hardening of steel.

The introduction of the bicycle, followed by that of the motor car and aeroplane, introduced an entirely new set of problems to the engineer, because in these machines it is essential that certain components should combine lightness in weight with great resistance to wear and considerable strength and ductility to resist impact and dynamic stresses. Now it does not require a very high standard of metallurgical knowledge to recognise the difficulty and almost complete impossibility of combining these multifarious properties in one and the same steel. A solution of the difficulty was, however, available in the adoption of the use of the process of case-hardening, and since that time the then little known process has become of immense commercial importance, and our knowledge of the subject has increased to a corresponding extent.

Briefly stated, the process of case-hardening demands the conversion of the outer layers of a low carbon steel into a high carbon steel while leaving the interior unaffected. Simple as this problem sounds its solution involves that the operator shall, in a sense, become a steel maker, because the fact must not be overlooked that the same statement describes the first operation in the making of high-class tool steel. Under these circumstances the importance of a knowledge of the principles underlying the process cannot be too strongly emphasised, and it is with the object of supplying some knowledge of these principles that this paper has been written.

Carburising Materials.

Obviously the most essential constituent of a case-hardening mixture is carbon, and the long experience of the steel maker has proved beyond all doubt that of all forms of carbon, wood charcoal is the most effective for the process of cementation, which process for the manufacture of high-grade tool steel is a standing testimony of the efficacy of simple wood charcoal as a carburising agent. But the case-hardening process presents problems which are not met with in total cementation process for the manufacture of blister steel. These problems will be apparent when we come to deal with the theory of the case-hardening process. Circumstances demand that the case-hardening process should be carried out at much lower temperatures than rule in the carrying out of cementation for steel making, and at these lower temperatures it is found that wood charcoal alone is slow and somewhat uncertain in its action. As far back as 1861 Caron discovered that the action of wood charcoal as a cement is vastly improved by the addition of barium carbonate, and the use of a mixture of 40 per cent. barium carbonate and 60 per cent. wood charcoal has been separately advocated by no less authorities than Guillet and Giolitti; in fact, the latter authority (in his book, which should be studied by all who are interested in the subject of case-hardening) states that this mixture is one of the best of all the solid cements. In the writer's experience the only objection to the use of barium carbonate lies in the difficulty of obtaining the material in a sufficiently pure form, most of the samples obtainable containing considerable proportions of barium sulphate, which is liable to be reduced to barium sulphide during the prolonged heating with carbon and, incidentally, to introduce sulphur into the case.

At this point it will be instructive to refer to the papers "Contribution to the Study of the Cementation of Iron," by the Russian investigator Fechtchenko-Tchopovsky, long abstracts of which appear in the Revue de Metallurgie, September, 1915, and April, 1916. This investigator's work is not very well known in this country, but it contains results and conclusions which are of the utmost importance to the industry. The first conclusion of importance is that the best wood charcoal for the production of a cement is obtained by carbonising wood for four hours at a temperature of 400 deg. C., such a process yielding a very compact form of charcoal from which the whole volatile matter has not been driven. He also states that the addition of leather is detrimental, and recommends that the charcoal should be crushed to a grain size of 1.5 to 3 mms. As a result of research on the compound cements additions to the wood charcoal are divided in to strong accelerators, inert materials and retarders. The strong accelerators consist of lithium, sodium, potassium and barium carbonates, sodium oxalate and acetate, potassium tartrate, chromate, ferricyanide and ferrocyanide. Strontium and cobalt carbonates are accelerators, calcium, magnesium, nickel, manganese, carbonates, calcium and alumin-carbides are inert, while sodium sulphate, sodium chloride, potassium sulphate and chloride retard the process of cementation. Accelerators act by inducing the formation of CO at high temperatures. Tchopovsky's final conclusions may be stated as follows:—

The most economical, rapid, uniform in action and energetic cement is one containing 70 per cent. wood charcoal and 30 per cent. anhydrous sodium carbonate.

The depth of carburisation is independent of the composition or quantity of cement employed, but depends entirely on the temperature at which the operation is carried out.

There is no object in using more than 1.5 grs. of carburising material per sq. cm. of surface of the object to be carburised.

There can be no question as to the efficacy of these two extremely simple carburising compounds, and of the two the author has a decided preference for the sodium carbonate charcoal mixture. A content of 30 per cent. anhydrous sodium carbonate is, however, too high, such a mixture having a tendency to clot during carburising owing to fusion of the alkali, more particularly after the material has been used several times. The author has used this mixture for many years, and has found that the best mixture for all round purposes is one containing from 12 to 15 per cent. of the alkali. This material can be used over and over again; in fact, until the whole of the material has disappeared owing to the natural losses which occur in the packing and unpacking of the work.

Heating.—This part of the process should be carried out at temperatures between 880 deg. and 950 deg. C., and during the whole operation the temperature should be most carefully controlled by means of pyrometers. In the great majority of cases a temperature of 900 deg. C. should be chosen, because at this temperature there is very little danger of the production of a super-

* Paper read before the Staffordshire Old Boys Metallurgical Association, January 3, 1920.

saturated case. For some purposes, however, more particularly in the case of components, which have to be subjected to a final grinding operation, it is desirable to produce a case which is supersaturated on the outside, and in such components the carburising should be effected at a temperature of 950 deg. C., which temperature would rarely or never be exceeded. A very potent contributor to supersaturation of the case is temperature fluctuations during the carburising process, a fact which will be made clear when we come to deal with the theory of the process. In the carburising operation it is very desirable that the temperature should be kept constant during the whole of the operation on the desired degree of heat has been obtained. Supersaturation of the case is the main cause of cracking and exfoliation, and should be rigidly avoided wherever possible, but if supersaturation is necessary then the components so treated should be subsequently handled with caution during both the hardening and grinding operations.

Broadly, it may be stated that the carbon content of the case is a function of the temperature of carburising, while the depth of the case is a function of the time during which the operation is carried out.

The rate of penetration of the mixture with which we are dealing at 900 deg. C., may be taken at from 8 to 10 thousandths of an inch per hour, but this is a figure which must be used with some caution, for it must not be forgotten that only gamma iron has the power of absorbing carbon into solution so that the actual peration of carburising does not begin until the metal has attained the temperature of the lower critical point, and then does not proceed very rapidly until the upper critical point has been passed. The introduction into the box of small test pieces which can be withdrawn at intervals as the operation proceeds, may act as an invaluable guide to the progress of the carburisation, the pre-determination of the time necessary to obtain a certain depth of case with different-sized components packed in boxes of various sizes is to a very large extent a matter of experience.

The next stage in the operation is to allow the material to cool down, preferably in boxes themselves. In the early days of case-hardening it was customary to quench direct from the pot, a practice which is still occasionally followed in the case of small articles, but the practice is not one to be recommended, as will be seen from the sequel.

During the carburising process the net result has been to convert the outer layers of a mild steel article for a depth of some 5 to 60 thousandths into a high carbon steel. Another and incidental action has been proceeding at the same time, namely, grain growth, consequent upon the maintenance of the steel at a temperature above its critical range for a considerable period of time. The resulting components are, therefore, in a dangerously brittle condition so that it becomes necessary to treat the steel in such a way as will not only harden the outer layers, but will also restore the ductility of the interior or core. This immediately brings us up against the difficulty of dealing with what is in effect a composite bar, and the difficulty has been entirely overcome by the introduction of the process known as double-quenching. The components are removed from the carburising material, heated up to a temperature of 900 deg. C. and quenched in water. Such a treatment has the effect of causing recrystallisation of the core, but it is obvious that the high carbon case will not be in its best condition after such drastic treatment, and final hardening is carried out by again heating to 780 deg. C. followed by quenching in water or oil, according to the hardness required in the case. Components which are subjected to impact stresses such as valve lifters and tappet rods should be slightly tempered to remove brittleness ,and this can be carried out at temperatures not exceeding 200 deg. C. without seriously interfering with the hardness of the case.

With regard to the steel used for case hardening, ideas on the subject are still widely variant, more particularly as to the sulphur phosphorus and manganese contents. A composition which has been found to give excellent results in this country is as follows:—

Carbon	...	...	0.15 per cent.
Silicon	...	...	0.10 per cent.
Sulphur	...	...	0.05 per cent. max.
Phosphorus	...	...	0.06 per cent. max.
Manganese	...	...	0.80 per cent.

but there are still authorities, more particularly American and Continental, who demand that the sulphur, phosphorus, and manganese contents should be low. In the experience of the author, sulphur and phosphorus do no positive harm so long as they do not exceed the limits set out above, and there can be no doubt that these materials contribute to the ease of machining of the components, a factor which is of vital importance from the production point of view, more particularly in view of the fact that many of the components used in the making up of cycles are produced in automatic machines. Again, a fairly high manganese not only contributes to the hardness of the case, but at the same time very materially improves the mechanical properties of the core.

Nickel case hardening steels containing up to 6 per cent. of nickel also find frequent application. (Guillet's 7 per cent. nickel steel.) This element has little or no effect on the rate of penetration, but does somewhat reduce the extreme hardness of the case obtainable in ordinary case-hardening steels. Case-hardening steels containing small quantities of both nickel and chromium are also applied to some extent in the motor-car and aeroplane industries.

The author then deals extensively with the theories underlying the case-hardening process and the mechanism of the absorption of carbon. This was then followed by a brief description of the common faults met with in the process.

Faults in Case-Hardening.—The main faults of case-hardening are soft spots, general softness and cracking of the case or exfoliation.

Soft Spots may be due to local presence of material on the work, which prevents carburising, or to irregular heating, *i.e.*, the temperature to which the various parts are heated is not uniform, or to irregular cooling. Faults due to the latter cause are distinguished by the development of local dark areas on etching.

General Softness is due to carburising at too low a temperature or to the removal of too much material in subsequent machining and grinding operations.

Cracking and Exfoliation are the most serious defects met with in case-hardening. Both are usually the result of supersaturation, resulting in the formation of structurally free cementite round the grains, although exfoliation may occur in components which do not possess a supersaturated case if the conditions of a sharp line of demarcation between the pearlite and unsaturated or hypoeutectoid zones. Such a state of affairs is brought about by very slow cooling after carburising at comparatively low temperatures.

Exfoliation is the name given to actual peeling away of the case, and is due to a sharp line of demarcation between the various zones, due to too slow cooling.

In connection with supersaturation it is interesting to note that Giolitti has shown that if the temperatures be kept constant no free cementite is produced, even at temperatures as high as 1,100 deg. C.

Cementations carried out in which the temperature oscillates between 900 and 1,000 deg. C. produces no free cementite, but considerable quantities are produced between 1,000 and 1,100 deg. C. We see, therefore, the importance of maintaining a uniform temperature during carburising.

It cannot be claimed that the whole field of case-hardening has been covered; such a task would necessitate the reading of at least half a dozen papers, but it is hoped that sufficient material has been supplied for the inauguration of a useful discussion.

Trade Talk.

THE national projectile factory at Dudley has been sold to Harper Bean, Limited.

THE Chepstow shipyard has been taken over by a Cardiff syndicate, headed by Lord Glanely.

THE Arbroath Town Council have received an inquiry from a Dundee firm for ground for a proposed shipyard at Arbroath.

DR. ED. ARDERN has joined Mr. S. E. Melling in practice as analytical and consulting chemists at the Cliff, Higher Broughton, Manchester.

LIEUT.-COL. J. H. W. FRANCIS has been appointed chief storekeeper and purchasing agent to the London & South-Western Railway at Nine Elms.

AN amalgamation has been effected between Wilkinson, Heywood & Clark, Limited, and Pinchin, Johnson & Company, Limited, Minerva House, Bevis Marks, London, E.C.3.

MR. W. MCKINNEL, a director of Samuel Osborn & Company, Limited, who has completed 50 years' service with the company, has been the recipient of a presentation from the officials and men.

THE whole of the 50,000 new ordinary £1 shares in William Cooke & Company, Limited, Sheffield, recently issued at 10s. per share premium, have been taken up by existing shareholders and the employés of the company.

THE inquiry which has been started by the Profiteering Act Department into iron and steel does not affect the trade as a whole. It is really in connection with the raw materials used in the manufacture of domestic hardware.

WE understand that Thos. W. Ward, Limited, of Silvertown and Sheffield, have purchased from the Ministry the whole of the new wrought iron, screwed and socketted, water piping, lying at a large dump in London, and comprising several thousand tons of various sizes from ¾-in. to 6-in. diameter.

IN consequence of the development of transportation on large pneumatic tyres, the Dunlop Rubber Company have issued a leaflet that should be read by all engaged in the carrying industry. It deals with tyre loads and inflation pressures needful to ensure the best service, and the factors that determine tyre life are succinctly summarised.

THE INTERIM INDUSTRIAL RECONSTRUCTION COMMITTEE of the Railway Carriage and Wagon Industry has passed the following resolution :—"This committee views with grave concern the statement made by the Minister of Transport to a deputation of Members of Parliament on December 10, as the statement has been widely circulated, before verification, to the prejudice of the trade."

NEGOTIATIONS have been concluded for the transfer of the Duffryn Steel and Tinplate Works, Morriston, to local purchasers, viz., Mr. Llewelyn Davies, Gorseinon, and Mr. F. R. Phillips, J.P., Pontardawe. There are sixteen tinplate mills and two sheet mills at these works, and the steel department is one of the largest in the district. Mr. Llewelyn Davies is associated with the Mardy and Pantyffynon Works and Mr. Phillips with the Bryn Works.

AN accident occurred at the shipyard of Messrs. William Gray & Company, Sunderland, during the gale on January 8. The wind caught the roof of a shed, tore it off, and hurled it on to the roof of a platers' and riveters' shed, in which a large number of men were working, some 30 of whom received injuries. The roof which was blown off was about 150 ft. by 40 ft., and it was hurled 80 yards across the yard before it fell. The yard was temporarily closed owing to the accident.

REALISING the great future of the Diesel engine for ship propulsion Sir W. G. Armstrong, Whitworth & Company, Limited, have entered into an agreement with the well-known Swiss firm of Sulzer Bros., whereby they acquire a licence to manufacture and sell, in Great Britain and the Colonies, two-cycle marine engines embodying the best features of the Sulzer system. Engines aggregating over 600,000 b.h.p. have now been built by Sulzer Bros. on the two-cycle principle.

WE have received from the Institute of Metals, 36, Victoria Street, Westminster, S.W.1, a copy of the syllabus for Session 1920 setting forth the programme of the Institute, and of the Local Sections. The syllabus shows how the Local Sections of the Institute are developing. The membership is now over 1,200, and applications for membership are being received so rapidly by Mr. Shaw Scott, the Secretary, that the forthcoming ballot on March 3 is likely to constitute a record. Copies of the new illustrated membership booklet can be had upon application.

J. SAMUEL WHITE & COMPANY, LIMITED, East Cowes, I.O.W., completed and delivered their 120th steel war vessel and 72nd steel torpedo craft on December 23. This was H.M.S. "Wivern," a destroyer of the improved "W" class, which was laid down on August 19, 1918, and launched on April 15, 1919. She is of 1,450 tons displacement, and 28,000 s.h.p. Steam is generated in three White-Forster water-tube boilers, each developing over 9,000 shaft horse-power. The ship is capable of carrying some 400 tons of oil fuel, which will enable her to run about 1,000 miles at full speed.

A PROFIT-SHARING scheme has been set in operation by Messrs. George Richards & Company, machine toolmakers, Broadheath, Altrincham. The scheme, after making provision out of the profits for a deduction of 7½ per cent. on the present day valuation of the firm's business, allocates the profits between the shareholders and the workpeople, and it is anticipated that the addition to the earnings of the latter will not be less than 50 per cent. Opportunity is given to the employés to invest the bonus in shares in the company, upon which the directors guarantee a payment of 7½ per cent.

SINCE the Armistice was signed the Ministry of Munitions has, says an official announcement, been steadily reducing its staff and vacating premises which it occupied during the war. On Armistice Day the staff of the Ministry numbered 25,144 persons. Systematic reduction of the staff began immediately, and on December 29, 1919, it had fallen to 9,500. As a result of special efforts made between August 1 and October 31, 1919, a staff reduction of over 4,000 was effected. During the period dating from November 1 of last year to the end of February, 1920, there will be a further reduction, the actual discharges numbering 2,500.

THE last large building site in Aldwych has been secured by Agricultural and General Engineers, Limited. This site has a frontage on Aldwych of about 213 ft., and an approximate area of 30,000 ft. The board of the Agricultural and General Engineers, Limited, with which company are associated Aveling & Porter, Limited, Barford & Perkins, Limited, E. H. Bentall & Company, Limited, Blackstone & Company, Limited, Chas. Burrell & Sons, Limited, Richard Garrett & Sons, Limited, J. & F. Howard, Limited, and others, have decided to erect commodious offices and show-room accommodation on this magnificent position.

AT at meeting of the executive council of the British Federation of Iron, Steel, Tinplate and Metal Merchants, a resolution was passed to the effect that "This meeting of the council of the British Federation of Iron, Steel, Tinplate, and Metal Merchants desires to make it known that the case of alleged profiteering brought by their late chairman, Sir Johnstone Wallace, against John Spencer & Sons, of Newburn, is regarded by them as a purely private affair, and in no way connected with the Federation, whose council was not consulted in the matter, and deplores the fact that their secretary was requested by Sir Johnstone Wallace in his private capacity to represent him."

A BILL "to make further provision in regard to the undertaking of the South Wales Electrical Power Dis-

tribution Company" has been deposited for introduction into Parliament next session. The Bill proposes to empower the company to issue £500,000 5 per cent. prior lien debenture stock "in addition to" the £318,148 prior lien debenture stock authorised in 1906, but not yet issued. The stock is to bear interest at 5 per cent. per annum. The Bill also proposes to empower the company "to create and issue such amount of 5 per cent. debenture stock as may be required," to issue to holders of deferred warrants £1 of debenture stock for every £1 secured by the warrants "in satisfaction and discharge of the amounts secured by such warrants as regards principal and interest."

DEVELOPMENTS are taking place at Llantrisant in connection with the iron ore industry. Mining operations on an extensive scale have been renewed at Pontyclun for the purpose of tapping the Taffs Well—Llanharry ore fields and deposits have been definitely proved in the immediate vicinity of the Hendy mine. This mine is being opened up by the Hendy Hematite Iron Ore Company, Limited, and buildings of a permanent character have been erected on the site under the supervision of Mr. J. Bennetts, manager. Iron ore mining ceased to be remunerative in this area in the latter part of last century, when, as the result of the importation of Spanish ores, several mines had to be abandoned. This inactivity continued until 1910, when operations were resumed by the Cardiff Hematite Iron Ore Company, Limited, at Llanharry.

THE executive committee of the Whitley Council in the wire trade has decided that all firms represented on the council be requested to make returns under the following headings:—(1) Wages paid; (2) capital; (3) contributions to insurance and state of local taxation; (4) aggregate amount distributed as interest; (5) taxed profits allocated to reserve and special depreciations; (6) Board of Trade returns; (7) tonnage of wire produce; (8) total number of men employed in the industry; (9) cost of coal, and (10) total cost of transport "in and out." These figures are to be drawn up and collated by chartered accountants. Figures relating to the percentages of sickness and unemployment and to the number of apprentices in the industry will be provided by the Wiredrawers' Society. The Joint Industrial Council has decided upon geographical districts for District Councils.

The fifth ordinary general meeting of the session of the Institution of Automobile Engineers was held on Wednesday, January 7, when Lieut.-Colonel D. J. Smith read a most interesting Paper on "The Use of Producer Gas for Motor Vehicles." The subject is one of pressing importance to-day, in view of the urgent need of increased transport and the necessity for the utmost economy in its use. A point of particular importance brought out in the Paper was the great variety of fuels which can be used with this plant, so that the possibilities of the introduction of mechanical transport into country districts both at home and abroad will be greatly increased. Before the reading of the above Paper, the premium kindly awarded by the Daimler Company for the best Paper read by a graduate during the session 1918-19 was awarded to Mr. L. Griffiths for his Paper on "High-Tension Magnetos." This is the second occasion in succession on which this premium has been won by the Coventry Branch of the Graduates' Section.

SIR JOHN RAMSDEN, BART., is actively pushing on the mining developments in the Stiperstones district, near Shrewsbury. Sir John, who has formed the Shropshire Mines Company, has acquired a number of lead mines in this district. The company have completed the Leigh Level, a scheme that was begun fifty years ago to draw off the water from the mines in this district, but never completed until now. To get over the transport difficulty the company have erected an aerial ropeway extending from the mines at the Bog to Minsterley, a distance of eight miles. At present the developments are being centred on the barytes mines. For the present it has been decided to put down at the Bog Mine two 400-h.p. engines to supply power for pumping. Winding plant is to be installed at Bunting's Shaft, and the Leigh Level is to be further driven through so as to reach the Wood Mine. At Perkin's Beach an air compressor is to be installed, and a light railway to take the ore to the aerial ropeway. The Hinglith Mine is being opened out rapidly, and the Rorrington and Gallen old mines are being opened up.

SIR W. G. ARMSTRONG, WHITWORTH & COMPANY, LIMITED, are making a bid for a position with the premier locomotive builders of the world. Their erstwhile ammunition works at Scotswood, on Tyneside, were allocated for the construction of locomotives. Immediately after the Armistice they commenced their reorganisation in this direction with a thoroughness which has brought immediate success. Within the short space of a year the vast munition plant has been swept away, the new plant installed, and the first Armstrong Whitworth locomotive—a powerful 0-8-0 type for the North-Eastern Railway—was completed and delivered from their works. At present the firm have the following orders on hand:—North-Eastern Railway Company, 0-8-0 with six-wheel tender; Midland & Great Western Railway of Ireland, 0-6-0 with six-wheel tender; Caledonian Railway, 4-4-0 with six-wheel tender; Great Southern & Western Railway (Ireland), 4-6-0 with six-wheel tender; Dutch Colonial Government Railway, 4-6-4; Leopoldina Railway, 4-6-0 with six-wheel tender; Trinidad Railway, 4-6-0 with six-wheel tender; Nigerian Railway. Aro class 4-8-0 with 8-wheel tender; Indian State North-Western Railways, 0-6-0 with six-wheel tender, Bombay, Baroda & Central India Railway, 2-8-0 with six-wheel tender; Madras & Southern Mahratta Railway, 2-8-0 with six-wheel tender; Buenos Aires Western Railway, 2-6-2; Belgian State Railways, 2-5-0, with six-wheel tender.

The Foundry Equipment Manufacturers' Association, organised in the United States about a year ago to promote and further the interests of its members by impressing upon foundrymen generally the advantages to be derived from the use of efficient foundry equipment, proposes now to broaden the scope of its activities by conducting a campaign of education on the proper care, maintenance and operation of such equipment after it has been installed. The members of this Association, with their comprehensive knowledge and experience of conditions and problems in all classes of foundries, have been in a particularly favourable position to accumulate facts and data on the subject. They now propose to embody this information in a series of monthly bulletins, to be issued during the coming year. These bulletins will be sent direct to the executives, superintendents and foremen of all the foundries in the United States and Canada. That they may receive the attention of the men interested they will be mailed to their home addresses. An adjustable, stiff cardboard cover will be sent with the first of the series, so that the bulletins may be filed as they are received, and thus be available for reference. The cover will be of convenient pocket size. Only one individual phase of the problem connected with each piece of foundry equipment will be considered in each of these bulletins. It is stated that they will be written in a concise, practical manner, and will contain a wealth of pertinent hints on the most efficient method of caring for and operating mechanical equipment to secure maximum production and service.

AT the inquest on the body of the man killed by the recent explosion at the Derwent Blast-furnaces, at Workington, Mr. C. Carlisle said they were making basic iron at the time. He thought the cause of the explosion was that the furnace was sticking at the top and driving freely at the bottom, and that the material contracted and there was a fall, and the explosion would be caused by the compressed gas. By the Inspector: The first report was that the furnace was not working so well, and there had been a slight slip, but no damage was done. Later, the report was that it was working well and doing well. It was a fine ore

(brown hematite), and they had never used it before for making that grade of iron. They often got slips, but had never had an explosion of that description before. They usually used red hematite. Explosions like this were common in America, but not so common here. It was a new furnace, and they added a new outlet for gas, to give greater safety, and that was twelve months ago. The jury found that death was due to an accident, caused by the explosion, and they suggested that in future the utmost vigilance should be exercised to see if there was any indication of slipping, or of any such condition as would lead to an explosion. The Factory Inspector had told them, the foreman continued, that he had spoken to Mr. Graham about the fine ore, and he had said he would have it mixed with larger ore. Mr. Carlisle said it was the intention of the company to mix the ore with lumpier ore. He admitted the ore was fine, but it was not always possible for them to pick and choose the ore.

THE claim of Dr. Arnold in regard to the alleged new high-speed steel, which has been so freely commented upon in the daily press, is criticised in a statement issued collectively by Darwin & Milner, Limited, Sybry, Searls & Company, Limited, and the Spartan Steel Company, Limited, manufacturers of the "Como" molybdenum super high-speed steel. This joint contribution points out that the companies concerned have been manufacturing tungstenless molybdenum high-speed steels for some considerable time, and have given very great attention to the theory and practice of alloy steels generally. They fully endorse Dr. Arnold's view that molybdenum in high-speed steel produces far better results than tungsten. They, however, dispute the claim that his formula is new, and also that vanadium has proved an efficient stabiliser of molybdenum when used with it. As a matter of fact not long after the introduction of tungsten high-speed steel, molybdenum high-speed steel, both with and without vanadium, was made in the United Kingdom, France, Germany, Luxembourg, Austria, and the United States similar to the formula which Dr. Arnold has now made public. The occasional startling results of such molybdenum mixtures, superior to the very best tungsten high-speed steel, induced many firms to plunge into schemes for producing molybdenum steels on an extensive scale, but all had to be abandoned because the resulting product lacked uniformity. Much of it was of excellent quality, but, on the other hand, batches of tools failed entirely when subjected to workshop tests, although they showed the correct analysis. In the cases where vanadium was added it failed to be uniform in bulk manufacture, just the same as the molybdenum steel without vanadium, consequently the makers fell back upon tungsten. They attribute Dr. Arnold's erroneous faith in vanadium as a stabiliser to molybdenum steel to the circumstance that he experimented merely on small quantities. However, only bulk production can disclose the presence or otherwise of a real stabilising element. "Como" steel, made under Mr. Kuehnrich's patents, contains cobalt as a stabiliser.

DORMAN, LONG & COMPANY, LIMITED, of Middlesbrough, have acquired the works of the Carlton Iron Company, Limited, of Stockton. Their acquisition includes the Carlton Ironworks at Stillington, consisting of three blast furnaces and an up-to-date coke oven and by-product plant, as well as the Mainsforth Colliery, near Ferryhill. The Carlton Iron Company, Limited, was registered in July, 1914, in reconstruction of a company of the some name, which was originally established half a century ago as the North of England Industrial Iron and Coal Company, Limited, the name being changed to the Carlton Iron Company in 1877. The authorised capital was £325,000 in shares of £1, £125,000 being 5 per cent. cumulative preference shares and £200,000 ordinary; of the preference shares £110,000 and of the ordinary shares £164,529 have been allotted, and are fully paid. There are also 5 per cent. mortgage debentures of £100 each for £153,600, repayable November 1, 2014. The allotment of share capital did not take place until after the close of the financial year ending April, 1915, in which year there was a profit of £122,889, of which £55,968 (being the profits from May 1 of the previous year, when the business was acquired from the old company, to October 24, the date when the certificate to commence business was issued to the new company) was placed to capital reserve, and debenture interest and the preference dividend were paid, leaving a balance of £51,478. In July, 1915, to enable the shareholders to participate in the previous year's profits, an interim dividend of 10 per cent. was declared on the ordinary shares. In the next three financial years (when the accounts were submitted together) a dividend at the rate of 10 per cent. was paid, free of income tax, the general reserve being £115,000, and £89,735 being carried forward. In 1918 Dorman, Long & Company, Limited, acquired the old-established business of Sir B. Samuelson & Company, Limited, and they hold all the ordinary share capital in Bell Bros., Limited, the bulk of the share capital in the North-Eastern Steel Company, Limited, and have large holdings in other concerns.

PARTICULARS of the offer from Guest, Keen & Nettlefolds, Limited, for the purchase of the ordinary shares in John Lysaght, Limited, have been issued to the ordinary shareholders of the last-named company. The offer is of three ordinary shares and four five per cent. cumulative second preference shares (free of income tax), ranking *pari passu* with the present issue of this class of shares in Guest, Keen & Nettlefolds, carrying dividends as from January 1, 1920, for every three ordinary shares in John Lysaght equivalent to one ordinary share and one and one-third preference shares in Guest, Keen & Nettlefolds for one ordinary share in John Lysaght. No fractions of shares will be issued, but any fraction of a share will be satisfied in cash on the footing that the second preference shares of Guest, Keen & Nettefolds are worth the nominal amount thereof. John Lysaght will remain a separate entity, but it is proposed to have an interchange of directors. The Earl of Bessborough, K.P., chairman of Guest, Keen & Nettlefolds, and Mr. Edward Steer, a deputy-chairman, will join the board of John Lysaght, while Mr. H. Seymour Berry, the chairman of John Lysaght, will become a deputy-chairman of Guest, Keen & Nettlefolds; and Messrs. D. R. Llewellyn, W. R. Lysaght, William E. Berry and H. G. Hill, directors of John Lysaght, will become directors of Guest, Keen & Nettlefolds. It is a term of the arrangement that, in the event of any present director of John Lysaght, Limited, being asked by Guest, Keen & Nettlefolds to retire, he shall receive, in addition to the director's fees due to him for the period up to the date of his retirement, a sum of £10,000. Appended are the principal details of the finances of the two companies taken from the last balance sheets:—Guest, Keen & Nettlefolds, Limited:—Liabilities: Paid-up share capital, £2,685,000; 4 per cent. debentures, £1,850,500; reserve funds, £3,145,000; sundry creditors, £1,234,224; profit and loss account, £425,187; total, £9,399,911. Assets: Fixed property, £2,821,200; stocks, £705,722; sundry debtors, £969,609; investments, £4,171,564; cash and bills, £671,815; total, £9,399,911. In October last the company capitalised £2,895,000 of the reserve fund by the distribution of one preference and two ordinary shares for every ordinary share held, so that the share capital now amounts to £7,583,000. John Lysaght, Limited:—Liabilities: Share capital, £1,000,000; 4½ per cent. debentures, £300,000; reserve fund, £800,000; creditors and credit balances, £1,740,345; profit and loss account, £965,482; total, £4,805,827. Assets: Cash, £360,613; investments, £1,745,784; debtors and debtor balances, £614,880; stock in trade, £614,026; fixed property, £1,470,522; total, £4,805,827. In October last the ordinary share capital was increased to £2,000,000 by the capitalisation of a portion of the reserve fund. The reserve fund shown in the balance-sheet is only £800,000 at the end of December, 1918, but in September last it was increased to £1,400,000 out of the balance available for disposal,

and to £1,600,000 by the transfer of £200,000 of specific but undisclosed reserves. The net disclosed profits of Guest, Keen in the year ending June 30 last were £417,140, and those of John Lysaght, Limited, £481,151, after providing for depreciation and bad debts. On September 10 last Mr. H. Seymour Berry, of Merthyr, acting in conjunction with Mr. D. R. Llewellyn and Viscountess Rhondda, acquired a controlling interest in John Lysaght, Limited. The terms of the fusion are reported to be as follows :— For each ordinary share of Messrs. Lysaght one ordinary share and 1 1-3 five per cent. tax free second preference share of Messrs. Guest, Keen & Nettlefolds, to rank for dividend from January 1. This is valued at 67s. per Lysaght share.

Personal.

THE late Mr. H. Glen, shipbuilder, of Scotstoun, left £4,204.

THE late Mr. H. B. Woodcock, forge manager at the Low Moor Works, left £38,232.

THE late Mr. C. Geddes, of Church Road, Huyton, near Liverpool, consulting engineer and naval architect, left estate valued at £22,177.

MR. J. MCINNES, Great Central mineral agent for the Sheffield district, is retiring after 50 years' service with the company.

MESSRS. D. LUKE, E. Walter Bielski, W. E. Wilson, and A. Vachell have been elected directors of Morgan, Wakley & Company, Limited.

MR. H. C. WATERSTON, the general works manager of the Scottish Iron and Steel Company, Limited, has been elected a director of the company.

MR. T. DARWIN, a director of Spear & Jackson, Limited, Etna Works, Sheffield, has just retired. He has been associated with the firm for over 60 years.

MR. H. D. LANGRIDGE has been appointed district traffic manager of the Manchester district of the Great Central Railway Company in succession to the late Mr. George J. Gibson.

MR. J. C. CROWTHER has, owing to continued ill-health, found it necessary to retire from Messrs. Stedman, Crowther & Company, 4, Lime Street, London, E.C.3, of which company he was senior partner.

MR. E. TODA, who for twenty years has been in charge of the offices in London of Messrs. Sota & Aznar, has retired. He has been succeeded by Messrs. A. Norton, Alejandro de la Sota Yzaguirre, and Alejandro de la Sota Aburto.

THE death occurred on Monday, January 5, at Brynawel, Averavon, of Mr. William Price Lewis, manager of the Copper Miners' Tinplate Works, Cwmavon. Mr. Lewis had been at Cwmavon for about two years, and was formerly at Lydney.

MR. G. F. CHAMBERS, of Daybrook, who has been secretary during the last four years of the Nottingham Society of Engineers, has just received the appointment of organising secretary of the James Watt Memorial and Research Fund (Engineering).

MR. A. GLUSTON, whose death has occurred at Worthing, held the position of superintendent engineer of the Walker Shipyard of Sir W. G. Armstrong, Whitworth & Company, Limited, from the year 1884 until June last, when he retired owing to ill-health.

LORD CURZON OF KEDLESTON is not now President of the Imperial Mineral Resources Bureau, though he held the office while he was Lord President of the Council. As the titular head of the Bureau is the Lord President of the Council, that position is now occupied by Mr. Balfour.

MR. D. J. PARSONS, of Kidderminster, has been appointed foundry superintendent of Messrs. Thos. Piggott & Company, Limited, Atlas Works, Spring Hill, Birmingham. A member of the late firm of Messrs. David Parsons & Sons, Limited, Hays Iron Foundry, Brierley Hill.

As previously noted, Mr. J. Denny has retired from the chairmanship of William Denny & Brothers, Limited, Dumbarton, but meantime remains one of the directors. He will be succeeded in the chairmanship by Colonel John M. Denny, and the deputy-chairman will be Mr. M. E. Denny.

Deaths.

THE death has taken place of Mr. T. E. Allan, a director of Robey & Company, Limited, engineers, Lincoln.

MR. R. B. SHEPHERD, secretary of the Cardiff Junction Dry Dock and Engineering Company, Limited, died on Tuesday, January 23, at the age of 46 years.

THE RIGHT HON. SIR JOHN T. BRUNNER, BT., chairman of Brunner, Mond & Company, Limited, who died on July 1, left estate of the gross value of £899,122 11s., the net personalty being £768,740 2s. 3d.

MR. E. JONES, of Middlesbrough, died on Monday, December 29. He founded in 1873, in conjunction with his brothers, the Ayrton Rolling Mills, Middlesbrough, now part of Messrs. Dorman, Long & Company's works. He was 91 years of age, and had been a member of the Middlesbrough Exchange for nearly 50 years.

THE death took place at Gosforth, on Monday, December 29, of Mr. J. Orde, the principal of Messrs. John Orde & Company, copper smiths and brass founders, Railway Arches, Pilgrim Street, Newcastle. The deceased gentleman, who was 50 years of age, was a native of the city, and succeeded his father in the coppersmith's business.

THE death took place suddenly, on December 30, of Mr. H. Cumberland, of Hagley Road, Edgbaston, Birmingham. The deceased gentleman, who was the second son of the late Mr. Thos. Cumberland, of Perry Bar, was associated with Messrs. Sutton & Ash, of Snow Hill, Birmingham, and was well known on the Birmingham Exchange.

MR. J. H. SWIFT, of Lyndhurst, Wadsley, managing director of J. H. Swift & Sons, Limited, tool manufacturers, Sheffield, died on January 1. Mr. Swift, who was 66 years of age, had been in the trade all his life. As a boy, he was with Messrs. S. & C. Wardlow; then for 26 years he was manager of Messrs. Leadbeater & Scott, and the firm of which he was the head has been in existence 20 years.

MR. F. C. WILD died on Monday, January 12, at Whirlow Court, Sheffield. Mr. Wild, who was 69 years of age, had been in indifferent health for several months. One of the best known manufacturers of the Sheffield district, he was head of the firm of J. & F. C. Wild, steel manufacturers, Borussia Works, Jericho Street, Sheffield. An ancestor of his, William Wylde, was an Assistant of the Cutlers' Company at the time of its incorporation in 1624, and from that time until to-day the family have had a close association with the Sheffield trade. The late Mr. Wild did not take any prominent part in public affairs, except in his position as a member of the Cutlers' Company. He was Master of that body in 1898.

WE regret to announce that Sir Charles S. Henry, M.P., died in London on Saturday, December 27. Sir Charles had been ill for several months, and had been greatly affected by the death of his only son, who was killed in the war. During the war he undertook several missions for the Government, accomplishing valuable work in America and Sweden. He was a popular member of the House of Commons. Sir Charles Henry was the son of the late Mr. J. S. Henry, of Adelaide, South Australia, and was born in 1860. He was the founder and managing director of C. S. Henry & Company, Limited, metal merchants, Leadenhall Street, London, E.C., and was created a Baronet in 1911. He unsuccessfully contested the Chelmsford Division in 1900, but was elected for the Wellington Division in 1906. In December, 1918, Sir Charles was returned unopposed as a Coalition Liberal for the Wrekin Division of Shropshire.

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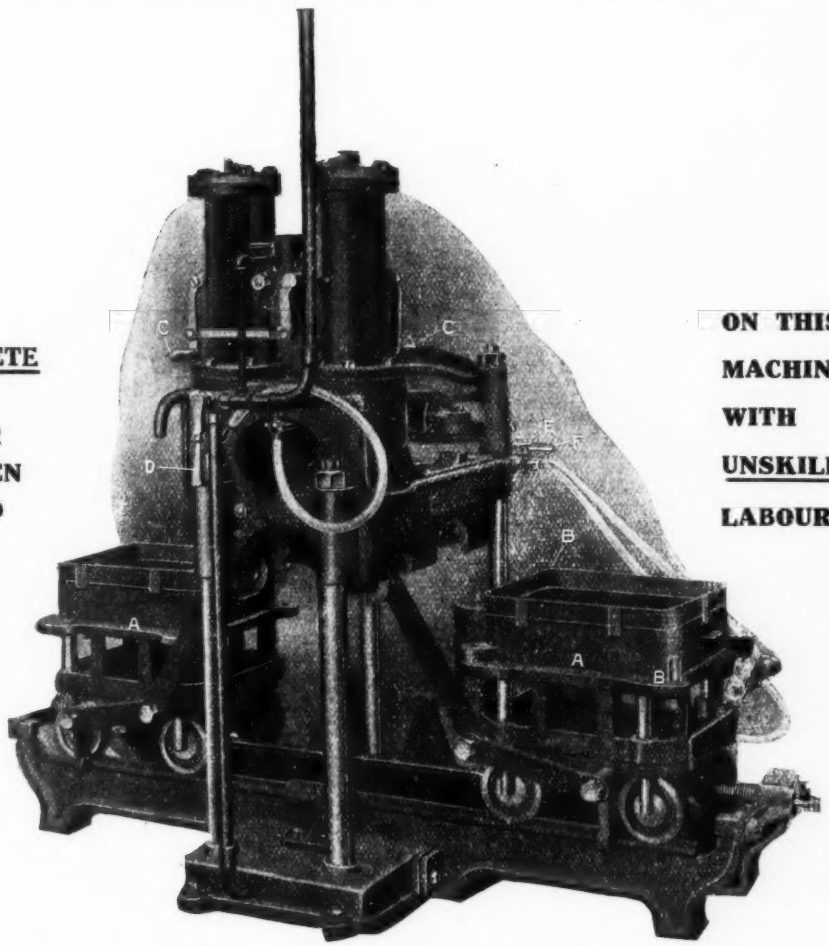

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Book Review.

Foundry Cost Accounting. By ROBERT E. BELT. Penton Publishing Company, Penton Buildings, Cleveland, Ohio. (Price $5.00, post free.)

The author of this work is the cost accountant of the American Malleable Castings Association, Cleveland, Ohio, and, as such, is in a unique position regarding technical information to enable him to deal authoritatively with the subject of foundry cost accounting. As explained in the preface, the object of the book is to set forth in a simple and direct manner, for the guidance of the foundry cost accountant, practical principles of accounting that are applicable to the foundry industry, and to show methods of collecting the cost data and of accurately determining production costs. Moreover, every principle of cost accounting set forth is not only applicable to foundry practice, but is being used in a thoroughly practicable manner, and is giving satisfactory results. Of the twelve chapters into which the book is divided the first five are devoted to setting forth the importance of an accurate knowledge of costs, the effects of uniform costing on competition, and an examination of plant practices and operating conditions met in foundries, while information is given regarding the installing and operating of a cost system, followed by details of accounting practice, which involves the use of records and inventories, numerous reproductions of which are included. Chapters six to nine deal with operating departments and department records, together with the classification and definition of accounts, monthly statements, and product costs. Three interesting chapters devoted respectively to depreciation, estimates, and profits, contain much useful information, which is explained where necessary by suitable examples. A perusal of this work leaves one with the impression that the author, besides being an accountant, is also a practical foundryman, and while in some respects the whole system as set forth is too elaborate for the small foundry, yet a suitable modifications of the suggestions to meet individual requirements should go far towards raising the efficiency of this important branch of engineering

Applications for Patents.

Adshead, H., and Ross, W. N. Process of treating rails, channel metal, etc. 31,052. December 11.

Alloy Welding Processes, Limited. Masks or shields for face and head of workmen. 30,026. December 2.

American Chain Company. Chains. 29,093. November 22

Arrol & Company, Sir W., and Anderson, D. M. Riveting-appliances. 28,997. November 21.

Bacon, N. H. Re-carburising molten steel in open-hearth furnace. 29,457. November 26.

Bugatti, E. Turning-tools for turret and automatic lathes, etc. 167. January 2. (France, October 17, 1919.)

Ballantine, W. B. Production of ferro-chrome alloys. 29,216. November 24.

Ballantine, W. B. Production of ferro-chrome. 30,108. December 2.

Ballantine, W. B. Production of ferro alloys. 30,472. December 5.

Batty, G. Method of casting ingots of steel, etc. 31,521. December 16.

Blaikie, J. R., and Phillips, R. W. L. Furnaces. 29,036. November 21.

British and Foreign Chemical Producers, Limited (Rheinische Kampferfabrik Ges.) Pickling iron or steel. 30,960. December 10

Chemical Engineering & Wilton's Patent Furnace Company. Liquid-fuel burners. 30,610. December 6.

Clements, G. F. Manufacture of pneumatic tools. 31,599. December 17.

Coggans, J. J. Fittings for tubes. 29,841. November 29.

Coles, S. O. Cowper-. Process for obtaining hard, springy copper by electro-deposition. 29,847. November 29.

Drury, F., and Williamson & Sons, G. H. Manufacture of blanks of sheet metal. 29,865. December 1.

Electrolytic Zinc Company. Recovery of zinc by electrolysis. 29,504. November 26. (Australia, December 3, '18.)

Fielding, J. Tube-forging apparatus. 30,590. December 6.

Frith, J. Furnaces. 28,630. November 19.

Geoghegan, J. T., and Gibson G. Alloy for welding cast-iron. 28,925. November 21.

Goldberg, J. S., and Gullborg, J. S. Die-casting machines. 29,409. November 25. (United States, May 24, '18.)

Hadfield, Sir R. A. Manufacture of alloy steel. 30,724. December 8. Manufacture of steel. 30,725. December 8.

Hadfield, Sir R. A. Manufacture of alloy steel and articles made therefrom. 29,761. November 28.

Hadfield, Sir R. A. Apparatus for rolling, shaping, etc., metals, etc. 29,762. November 28.

Hanley, R. Furnaces. 29,341. November 25.

Harvey, R. Furnace for locally heating metals. 29,069. November 22.

Heide, H. C. (*Maschinenfabrik Oberschoneweide Akt.-Ges.*). Revolving head for turning lathes, turret lathes, etc. 28,715. November 19.

Hurst, J. E., and Stokes, F. W. Manufacture of steel ingots. 28,483. November 17.

Hurst, J. E. Centrifugal casting-machines. 28,484 28,485. November 17.

Hurst, J. E. Moulds for centrifual casting-machines 28,544. November 18.

Hurst, J. E. Aluminium alloys. 28,546. November 18.

Icke, S. C., and Miller, R Tool-holders for lathes, shaping, planing, etc., machines. 29,107 November 22

Kilby, J. N. Re-carburising molten steel in open-hearth furnaces. 29,457. November 26.

Lawley, P. Tool-holder for lathes, etc. 29,170. November 24.

McKune, F. B. Open-hearth furnaces. 30,447. December 5.

Metallindustrie Schiele & Bruchsaler. Production of aluminium castings. 65. January 2. (Germany, February 18, 1918.)

Metals Extraction Corporation. Purification of zinc solutions. 31,936. December 19.

Middlemiss, E. T. Leaching and separation of ores, etc. 28,633. November 19.

Morrison, J. Air inlet casting for ascension pipes of product coke ovens. 29,676. November 28.

Neal, W. H. Dies and die blocks for forging machines. 31,470. December 16.

Peters, T. H. Process for conglomeration of metal chips and filings for fusion by heat. 30,482. December 5.

Sheffield Steel Products, Limited. Manufacture of blanks for cutlery. 105. January 2.

Snead & Company Iron Works. Joining metal parts. 28,640. November 19. (United States, January 30.)

Stören, R. Treating weakly magnetic iron ore containing sulphides as a secondary constituent. 31,814. December 18.

Underwood, F. B. Rolling sections in metal. 31,358 December 12.

Vautin, C. Smelting zinc. 30,592. December 6.

Webster & Bennett. Turret heads for machine tools. 27,878. November 11.

Wilson Welder & Metals Company. Process of welding. 31,578. December 16. (United States, October 31, 1917.)

Wright, D. Smelting or reduction of metallic ores, etc. 22. January 2.

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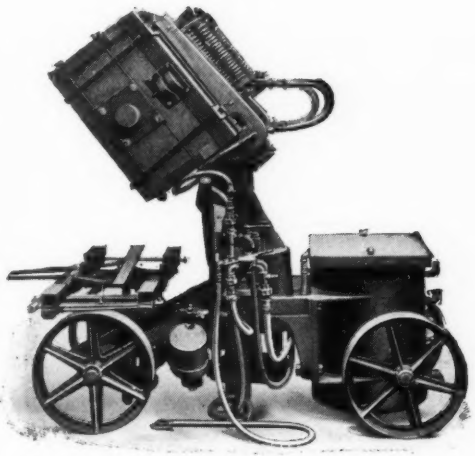

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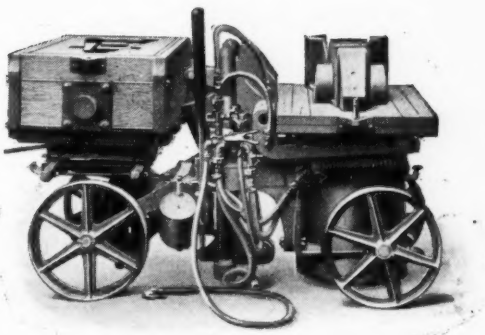

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New Companies.

Rudolf, Grubb, Lens & Rowland Engineering Works, Limited.—Capital £5,000 in £1 shares.

Riddell & Company, Limited.—Capital £10,000 in £1 shares, to carry on business as engineers.

R. & R. Gallagher, Limited.—Capital £20,000 in £1 shares, to carry on the business of engineers.

A. E. Lynes & Company, Limited.—Capital £1,000 in £1 shares, to carry on the business of engineers, etc.

Farmer Brothers (Shifnal), Limited.—Capital £5,000 in £1 shares, to carry on the business of engineers.

Sibley & Company, Limited.—Capital £20,000 in £1 shares. Registered office: Parett Iron Works, Martock.

National Metal Company, Limited.—Capital £10,000 in £1 shares. Registered office: 193, Broomloan Road, Govan.

Reliance Rope Attachment Company, Limited.—Capital £5,000 in £1 shares. Registered office: Bute Docks, Cardiff.

John Thornewill & Company, Limited.—Capital £15,000 in £1 shares, to carry on the business of iron merchants.

H. F. Stephen, Limited. — Capital £10,000 in £1 shares, to carry on the business of electricians and general engineers.

Dean's Electrical & Engineering Company, Limited.—Capital £1,000 in £1 shares. First directors: H. J. Dean and R. Lavie.

Andover Engineering Company, Limited.—Capital £1,000 in £1 shares. Registered office: 6, Andover Street, Birmingham.

Electro-Dynamic Construction Company, Limited.—Capital £10,000 in £1 shares. Registered office: 4, New Cross Road, S.E.

Werry Engine Syndicate, Limited.—Capital £10,000 in £1 shares. Registered office: Norfolk House, Norfolk Street, Strand, W.C.

Wolverhampton Hardware Company, Limited.—Capital £5,000 in £1 shares. Registered office: 43, Chancery Lane, London, W.C.

W. Banks & Company, Limited.—Capital £15,000 in £1 shares, to carry on the business of engineers. Registered office: 24, Madeley Street, Hull.

E. Horace Holme, Limited.—Capital £30,000 in £1 shares, to carry on business as wire chain manufacturers. Registered office: 472, Caledonian Road, N.

Ira Miller & Company, Limited.—Capital £15,000 in £1 shares, to carry on the business of engineers. Registered office: 94, Paul Street, Finsbury, E.C.

Ernest Scragg & Sons, Limited.—Capital £5,000 in £1 shares, to carry on the business of engineers. Registered office: 32-6, Paradise Street, Macclesfield.

Fred. Howard, Limited. — Capital £20,000 in £1 shares, to carry on the business of machinery merchants. Registered office: 137, Oldham Road, Middleton.

Ascog, Limited.—Capital £20,000 in £1 shares (6,000 preference), to carry on the business of iron merchants. Registered office: 24, West Heath Drive, Hampstead.

Powrlok & Company, Limited.—Capital £50,000 in £1 shares, to carry on the business of gear engineers, etc. Registered office: 24-6, Maddox Street, W.

Wicker & Parsons, Limited.—Capital £5,000 in £1 shares, to carry on the business of metal workers. Registered office:—38, Snow Hill, Birmingham.

John Ireland & Company, Limited.—Capital £6,000 in £1 shares, to carry on the business of engineers. Registered office: 71b, Gowan Avenue, Fulham, S.W.

Blunt & Wray, Limited.—Capital £12,000 in £1 shares, to carry on the business of metal craftsmen. Registered office: 70, Salisbury Road, Kilburn, N.W.6.

Harry F. Atkins, Limited.—Capital £50,000 in £1 shares, to carry on the business of machine tool manufacturers. Registered office: Old Fletton, Peterborough.

P. C. Pope, Limited.—Capital £5,000 in 4,985 ordinary of £1, and 300 management of 1s., to carry on business as engineers. Registered office: 96, Great Tower Street, E.C.

Colley, Meikle & Company, Limited.—Capital £15,000 in £1 shares, to carry on the business of engineers. Registered office: Colmic House, 15, Great James Street, W.C.1.

H. Backhouse & Company (Sheffield), Limited. — Capital £5,000 in £1 shares, to carry on the business of iron manufacturers. Registered office: 36, St. Thomas Street, Sheffield.

Holders, Limited.—Capital £10,000 in £1 shares, to carry on the business of electrical, mechanical, and general engineers, etc. Registered office: 87, Hanover Street, Edinburgh.

Humphries, Lee & Company, Limited.—Capital £10,000 in £1 shares, to carry on the business of engineers. Registered office: Independent Buildings, 21, Fargate, Sheffield.

Williams & Moffat, Limited.—Capital £1,000 in £1 shares, to carry on the business of mechanical and electrical engineers, etc. Registered office: Cateswell Road, Bordesley Green, Birmingham.

Hodgetts Bros., Limited.—Capital £30,000 in £1 shares, to carry on the business of metal-work manufacturers. Registered office:—117, Cherrywood Road, Bordesley Green, Birmingham.

George Steel & Company, Limited.—Capital £1,000 in £1 shares, to carry on the business of brass and iron founders, etc. Registered office: Grenville Buildings, 12, Cherry Street, Birmingham.

Kirkstall Forge, Limited.—Capital £500,000 in £1 shares, to enter into an agreement with the Kirkstall Forge Company, Limited. First directors: A. E. Butler, B. F. Butler and H. M. Butler.

Westwood Engineering Company (Wigan), Limited.—Capital £50,000 in £1 shares. First directors: J. W. Howarth, H. H. Timberlake, H. F. N. Timberlake, W. R. Gregson, and W. D. Williamson.

Crowthorn Engineering Company, Limited.—Capital £30,000 in £1 shares, to take over the business of an engineer and machine tool maker carried on by W. Moss at Ryecroft Street, Ashton-under-Lyne.

L. Herve, Limited.—Capital £50,000 in £1 shares, to carry on the business of screw manufacturers, etc. Permanent directors: F. W. and L. Hervé. Registered office: 34, Bentley Road, Dalston, N.

Rowland Cole & Company, Limited.—Capital £5,000 in £1 shares, to carry on at Cradley Heath the business of manufacturers of and dealers in chains, etc. Registered office: Foxoak Street, Cradley Heath.

Bourne Metal Works, Limited.—Capital £1,500 in £1 shares. First directors: A. H. Bunce, G. F. Curson, F. Whiffen and J. H. Whiffen. Secretary: J. H. Whiffen. Registered office: Bourne Road, Bexley.

United Foundry Company, Limited.—Capital £50,000 in £1 shares. First directors: J. King, A. S. Malcolm, A. W. Steven, E. Le Q. Herbert, P. Deas, T. Downie, and J. Fulton. Registered office: 142, St. Vincent Street, Glasgow.

Albert Eddleston, Limited.—Capital £2,000 in £1 shares, to carry on the business of manufacturers of and dealers in iron goods and scrap metal. Permanent director: A. Eddleston. Registered office: 48, Alma Place, North Shields.

Allan, Whyte & Company, Limited.—Capital £100,000 in £1 shares, to acquire the business of wire rope manufacturers carried on by Allan, Whyte & Company. Registered office: Clyde Patent Wire Rope Works, Lloyd Street, Rutherglen.

Judge, Robinson & Company, Limited. — Capital £1,000 in £1 shares, to take over the business of engineers and tool-makers carried on by B. H. Judge and R. P. Robinson, at Star Works, Boston Street, Sheffield, as Judge, Robinson & Company.

Donald Brown & Company, Limited.—Capital £50,000 in £1 shares, to take over the business of an engineer lately carried on by D. Brown at Heaton Junction, Newcastle-on-Tyne. Registered office: Celtic Works, Heaton Junction, Newcastle-on-Tyne.

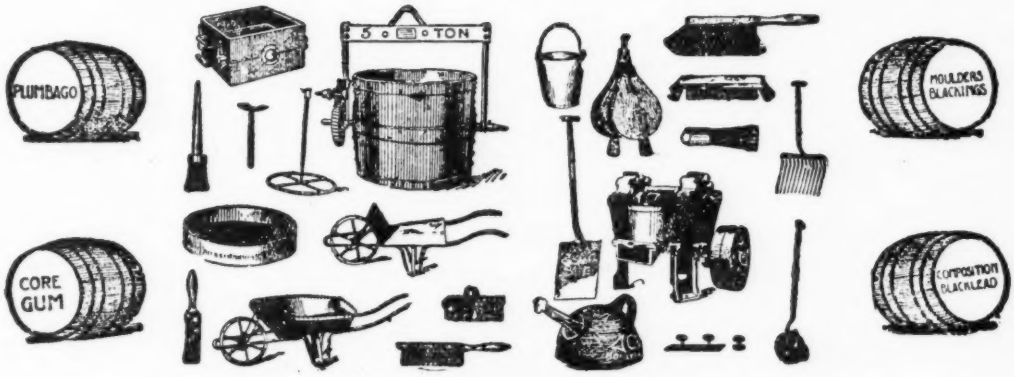
H. T. Newbigin, Limited. — Capital £5,000 in £1 shares, to carry on the business of engineers, etc., and to acquire the business carried on at 3, St. Nicholas'

Telephone: 21, Pennistone. Telegrams: "Durrans, Pennistone."

Established 1863.

JAS. DURRANS & SONS,

Phœnix Works, Penistone, Near Sheffield.



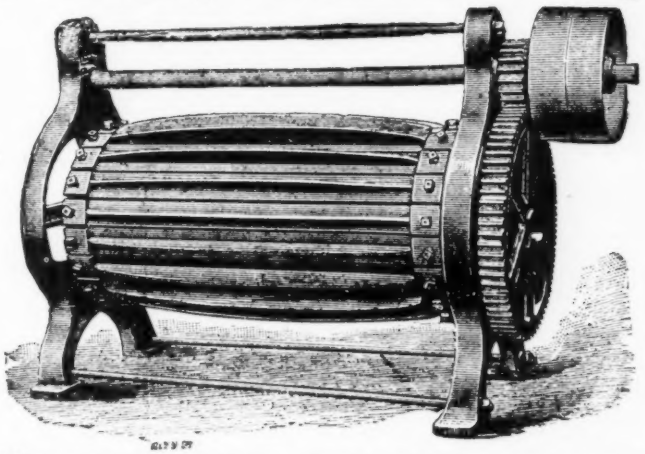
Manufacturers of all

FOUNDRY EQUIPMENTS

COMPOSITION BLACK LEAD, PLUMBAGO, CORE GUM, WHITE DUST & COAL DUST

Ladles, Cupolas, Fire Bricks, Gannister, Stone Flux, Loam and Sand Mills, Casting Cleaners, Studs, Chaplets, Pipe Nails, Sprigs, Brushes, Wire Brushes, Core Ropes, Bellows, Buckets, Spades, Forks, Riddles, Sieves, Barrows, Etc.

Improved Foundry Rattler or Fettling Drum.



These Machines are invaluable for a Foundry, doing a larger amount of work of a superior quality, in a much shorter time than can be done by hand, without skilled labour.

The following testimonial explains itself :—

"Dear Sirs,—We have been using your best Blacking for a large number of years, and always use it on our large Ingot Moulds, which, as you know, we have made up to 85 tons in weight.

Yours faithfully, THE BRIGHTSIDE FOUNDRY & ENGINEERING CO., LD.

Buildings, Newcastle, as H. T. Newbigin. First directors: H. T. Newbigin and G. D. McGlashan.

Smyth-Tyrrell & Cook, Limited.—Capital £10,000 in £1 shares, to take over the business of manufacturers of standard and special gauges and engineers' small tools carried on by F. Smyth-Tyrrell and A. Cook at New Writtle Street, Chelmsford, as Smyth-Tyrrell & Cook.

E. and A. Smith & Company, Limited. — Capital £200,000 in £1 shares, to carry on the business of wire-drawers, etc. First directors: Harry Smith, F. Smith, E. Smith, A. Smith, Herbert Smith, and E. Smith, jun. Registered office: Pyenor Hall Works, Cleckheaton.

Steel Wire Company, Limited.—Capital £700,000 in £1 shares. First directors: E. Smith, A. Smith, H. Smith, Herbert Smith, F. Smith, and E. Smith, junr., all being directors of the Doncaster Wire Company, Limited, Ordsal Wire Company, Limited, and E. & A. Smith Company, Limited.

James Blumer & Company, Limited.—Capital £200,000 in £1 shares, to take over the business carried on at Sunderland as John Blumer & Company, and to carry on the business of shipbuilders and repairers, etc. W. Blumer is permanent director Registered office: North Dock, Sunderland.

Thomas Diamond & Company, Limited. — Capital £150,000 in £1 shares, to take over the business of Thomas Diamond & Company, and to carry on the business of shipbuilders, etc. First directors: W. H. Diamond, J. Diamond, and G. L. Diamond. Registered office: East Bute Dock, Cardiff.

Butler Machine Tool Company, Limited.—Capital £200,000 in £1 shares (100,000 preferred), to take over the business carried on by J. Butler & Company at Victoria Ironworks and elsewhere in Halifax. First directors: Harold and Herbert Butler. Registered office: Victoria Ironworks, Adelaide Street, Halifax.

B.S.A. Guns, Limited.—Capital £600,000 in £1 shares, to acquire the small arms branch of the business of the Birmingham Small Arms Company, Limited. First directors: Sir Hallewell Rogers, P. Martin, Brigadier-General Sir Hy. C. L. Holden, K.C.B., and Captain K. R. Davis.

J. and G. Archibald, Limited.—Capital £3,000 in £1 shares, to take over the business of iron and steel merchants, carried on by J. Archibald and G. A. Archibald at Gilesgate Goods Yard, Durham, as J. and G. Archibald. First directors: J. Archibald and Mrs. B. Archibald (provisional).

Morton, Muir & Company, Limited.—Capital £30,000 in £1 shares, to carry on the business of iron, steel, and metal merchants, and to acquire the business carried on by W. C. Daniel, under the style of Morton, Muir & Company, at Glasgow, and by W. N. Gibb, at Cleland. Registered office: 90, Mitchell Street, Glasgow.

Inter-Continental Engineering Company, Limited.—Capital £103,500 in 100,000 preference shares of £1 each and 70,000 deferred shares of 1s. each. First directors: Col. Sir Edward W. D. Ward, Bart. (chairman), Right Hon. Earl Fitzwilliam, Capt. E. S. Ward, H. H. Powell, A. Hutchings, J. A. Smith and J. N. Willys. Secretary, E. Pryer. Registered office:—20, Conduit Street, London, W.1.

Colby Brothers, Limited.—Capital £300,000 in £1 shares, to take over the businesses of shipbuilders, etc., carried on by Colby Brothers, Limited, at Oulton Broad and Lowestoft, and J. W. Brooks & Company, Limited, at their No. 3 Works at Oulton Broad. First directors: J. W. Colby (permanent chairman), G. H. Bullimore (permanent vice-chairman), F. A. Bainbridge, H. Sexton, and W. C. Webster. Secretary, P. J. White. Registered office: Oulton Road, Lowestoft.

THE "REAL PRESSURE" DIE CASTING PLANTS.

Contractors to the War Office, Admiralty, Ministry of Munitions and Air Ministry.

DIE-CAST IT.

Magneto Parts, Ball Bearing Parts, Die-Cast with Steel Balls in complete. Bearings, Screw Threads, Gears, Accumulators, Grids, Wheels, Rings, etc., etc.

The only heat controlled die-casting plant on the world's market.

Pressure of 7 tons obtained.

Complete castings up to 40-lbs. white-metal alloys can be made in one operation.

Interchangeable nozzles for different sizes of castings.

Interchangeable pots.

For the production of "dead-size die castings" in tin, lead, zinc and aluminium alloys and all white metals.

SOLE MAKERS.

MONOMETER MANUFACTURING Co.

Browning Street, BIRMINGHAM.

Telegrams: "Monometer, Birmingham." **Telephone:** Midland 553.

WE SUPPLY **THE** LEADING FIRMS IN THE TRADE WITH

FOUNDRY BLACKINGS

OF ALL KINDS

COAL DUST, CHARCOAL, PLUMBAGO and BLACK-LEAD CORE GUMS and all Foundry Requisites, and have done so si ce 1831.

I. & I. WALKER, EFFINGHAM MILLS, ROTHERHAM.

Our Specialite is Studying Special Requirements.

KINDLY HAND US YOUR ENQUIRIES.

Dust Fan.

High Pressure Fans.

Volumetric Fan.

Fans for Ventilation, for Dust Removal, for Induced & Forced Draft on Boilers.

...TRADE... SIROCCO ...MARK...

FANS

Cupola and Forge Fire Fans for large or small duties. Reliable and efficient.

Davidson & Co., Limited.,

Sirocco Engineering Works.

BELFAST.

GANISTER, CUPOLA BLOCKS, FIRE BRICKS,

FIRE CLAY.

Silica Bricks, Tuyeres, Stoppers, Nozzles, &c.

STEEL MOULDERS' COMPOSITION, SILICA CEMENT.

J. GRAYSON LOWOOD & Co., Ltd.,

DEEPCAR nr. SHEFFIELD.

Telegrams: "LOWOOD, DEEPCAR."

MONTHLY PRICE LIST.

The undermentioned prices, unless otherwise specified, are those obtaining at the commencement of the current month.

Pig-Iron.

	Home £ s. d.
Hematite—	
East Coast Mixed Nos.	11 0 0
East Coast No. 1	11 2 6
West Coast Mixed Nos.	11 5 0
Scottish Mixed Nos.	11 2 6
Welsh Mixed Nos.	11 15 0
Cleveland—	
No. 1	9 2 6
No. 3 foundry G.M.B.	8 15 0
No. 4 foundry	8 15 0
No. 4 forge	8 15 0
Basic	9 0 0
Derbyshire, Leices., and Notts—	
No. 4 forge	9 15 0
No. 3 foundry	10 0 0
No. 2 foundry	10 2 0
No. 1 foundry	10 4 0
Basic	10 2 6
Northamptonshire—	
No. 4 forge	9 10 0
No. 4 foundry	9 11 0
No. 3 foundry	9 12 0
No. 2 foundry	9 13 6
No. 1 foundry	9 15 6
Basic	10 2 6
South Staffordshire, Shropshire and Worcestershire—	
Part-mine forge	10 5 0
Part-mine foundry	10 7 6
Common Staffs.	9 5 0
All-mine forge	10 5 0
All-mine foundry	10 10 0
Warm-air forge	11 15 0
Warm-air foundry	12 5 0
Cold blast	14 17 6
Basic	9 17 6
Scottish—	
Foundry	10 10 0
Delivered in Manchester—	
*Derbyshire, No. 3	—
*Cleveland, No. 3	—
*Scottish, No. 3	—
* Merchant prices.	
Delivered in Sheffield—	
East Coast hematite	—
Derbyshire basic	—
Lincolnshire basic	—
Do. No. 3 foundry	—
Do. forge	—

High-Speed Tool Steel.

	s. d.
Finished bars, 14 per cent. Tungsten	2 11
Finished bars, 18 per cent. Tungsten	3 6
Per lb. delivered buyers' works.	
Extras—	
Rounds and squares 3 in. to 8 in. inclusive	4d. per lb.
Rounds and squares under ½ in. to ¼ in.	3d. ,,
Flats under 1 in. by ½ in. to ½ in. by ¼ in., and all sizes over four times 3 in width and over thickness	3d. ,,
Bevels of approved sizes and sections	6d. ,,
If in Coils	3d. ,,
Packing	4s. per cwt
Bars cut to length	10% extra
Scrap from High-Speed Tool Steel—	
Scrap pieces, 5d.	
Turnings and Swarf, 3d.	
Per lb. net, d/d steel-makers' works.	

Ferro-Alloys.

Ferro-Titanium—23/25% Ti. carbonless, 1/6.
Ferro-Tungsten.—75/80%, 2/10.
Ferro-Molybdenum.—70/80%, Mo., 9/3.
Ferro-Vanadium.—35/40%, Va., 34/6.
Metallic-Manganese.—98/99%, carbonless, 3/9. (All per lb.).
Ferro-Phosphorus.—20/25%, P. £16 10 0
Ferro-Chrome.—4/6%, car., £45 0 0.
Ferro-Chrome.—6/8%, car., £45 0 0.
Ferro-Chrome.—8/10%, car., £45 0 0.
Ferro-Chrome —Specially refined, basis 60% chr., max. 2% car., £100 0 0.
Ferro-Silicon.—45/50% Si., £20 0 0 d/d. at Sheffield Steelworks.
Ferro-Manganese.—80%, £28 10s. loose, £29 10s. packed. Export £30, according to destination. (All per ton.)

Copper.

	£ s. d.	£ s. d.
Standard cash	117 15 0	118 0 0
Three months	119 15 0	120 0 0
Electrolytic	122 10 0	123 0 0
Tough	121 0 0	123 0 0
Best selected	122 0 0	123 0 0
Sheets	167 0 0	—
India	166 0 0	167 0 0
American electrolytic spot	123 0 0	—
Do. Feb.	122 0 0	122 10 0
Official average price cash, Dec.		103 17 1½
Do. Three months, Dec.		105 9 5½
Do. Settlement, Dec.		103 16 8
Do. Electro, Dec.		114 6 8
Do. B.S., Dec.		113 7 6
Average spot price, copper, Dec.		103 14 6½
Do. Electro, Dec.		113 0 11½

Tin.

	£ s. d.	£ s. d.
Cash	389 5 0	389 10 0
Three months	388 15 0	389 0 0
English	387 0 0	—
Bars	389 0 0	—
Refined	—	—
Straits	393 15 0	—
Australian		391 5 0
Eastern		383 0 0
Banca		391 5 0
Official average price, cash, Dec.		314 5 1¾
Do. Three months, Dec.		315 16 6½
Do. Settlement, Dec,		314 4 3½
Average spot price, Dec.		314 3 4

Spelter.

	£ s. d.	£ s. d.
Ordinary	58 0 0	—
Remelted	54 0 0	55 0 0
Hard	46 0 0	47 0 0
Electro 99,9	61 7 6	—
English	60 10 0	61 0 0
India	54 0 0	56 0 0
Zinc dust	70 0 0	80 0 0
Do. English	—	—
Zinc ashes, per cent. 70%	—	17 10 0
Official average price, Dec.		53 9 2½
Average spot price, Dec.		53 1 6½

Lead.

Soft foreign (net)	46 0 0
English	47 10 0
Official average price, Dec.	41 7 8½
Average spot price, Dec.	41 5 7½

Antimony.

English regulus	69 0 0
Chinese	64 0 0
Crude	59 0 0
Ore	Nominal.

Aluminium.

Virgin Metal 98/99—.. .. ..150 0 0 per ton.

Phosphor Bronze.

Ingots.	Per ton.
Alloy No. I. or II.	—
III., IV., or V.	—
IV. or VII	—
VIII.	—
XI.	—
Cast Strips and Ingots	—
Castings.	**Per lb.**
I. or II.	—
III., IV. or V.	—
IV. or VII.	—
VIII.	—
XI.	—
No. VII., Chill, Cast, Solid	—
,, Cored Bars	—

Delivery 2 Cwt. free to any town.
10 per cent. Phosphor Copper .. £50 above price of best selected copper.
15 per cent. Phosphor Copper .. £70 above price B.S.
Phosphor Tin (5 per cent.) .. .. £30 above price of English Ingots.
Phosphor-bronze prices supplied by Charles Clifford and Son, Limited, Fazeley Street Mills, Birmingham.

*Chromium (Metallic).

98/99— purity, per lb. 6/6 — —

*Nickel.

In cubes, 98/99— purity per ton ..£220 0 0

Nickel Silver.

	per lb.
Ingots for raising	1/7 – 2/–
Ingots for Spoons and Forks	1/7 – 2/–
,, rolled to spoon size	1/10 – 2/3

*Tungsten Metal Powder.

	per lb.
96/98— purity	3/6

*Molybdenum Metal.

96/98— purity, per lb — —

*Cobalt Metal.

	£ s. d.
97— purity, per lb.	0 12 0

Quicksilver.

75 lb. bottle 22 12 6
* Net, delivered Sheffield Works.

Scrap Iron and Steel.

Cleveland.	s. d.	s. d.
Steel scrap, heavy melting	—	—
Iron scrap cast (cupola metal)	—	—
(London f.o.b.).		
Heavy steel		135 0
Light ,,		90 0
Heavy cast		120 0

Steel Scrap.

Without Analysis—	Per ton £ s. d.
Heavy steel melting scrap	8 0 0
Steel planings, turnings and borings	7 5 0
Steel planings, turnings and borings mixed with wrought-iron or other material	7 0 0
Other classes of steel scrap, whether or not mixed	7 10 0
F.o.r. or in barge at nearest siding or wharf.	
With Analysis—	
Heavy steel melting scrap not over 0.04 per cent. p. and s.	8 10 0
Heavy steel melting scrap not over 0.05 per cent. p. and s.	8 10 0

Wrought-Iron Scrap.

	£ s. d.
(1) (a) W.I. plates and sections, not less than ⅛ in. thick, reasonably clear of rivets, flanged ends, etc., suitable for shearing; cable scrap and chain scrap not less than ¼ in. dia.	8 10 0
(b) Heavy W.I. scrap not less than ¼ in. thick including horseshoes, rivets and bolts, and scrap therefrom	8 10 0
(c) W.I. scrap under ¼ in. thick, and all W.I. scrap not included in classes 1, 2 and 3.	8 10 0
(2) Mixed W.I. scrap	7 0 0
(3) Wrought-iron planings, turnings and borings mixed with steel or other materials	4 15 0
(4) W.I. planings, turnings and borings	5 12 6

Cast-Iron Scrap.

	£ s. d.
Heavy ord., broken, between 1½ cwt. and 10 cwt. each	7 5 0
Heavy machinery, broken between 1½ cwt. and 10 cwt. each	7 10 0
Cold blast, broken, between 1½ cwt., and 10 cwt.	9 5 0
Ingot mould, unbroken	8 10 0
Do. broken, between 5 cwt. and 2 tons each	8 15 0
Do. between 1½ cwt. and 5 cwt. each	9 0 0
Railway chairs, whole or broken for remelting	7 10 0
Heavy lumps, not exceeding 2 tons each	7 2 6
Light	6 15 0
Burnt, broken ready for cupola	6 0 0
Burnt fire bars	6 10 0
Turnings and borings, for iron and steel makers	5 15 0

Old Metal.

London—	£ s. d.
Copper (clean)	100 0 0
Brass (clean)	56 0 0
Lead (less usual draft)	37 0 0
Tea lead	35 10 0
Zinc	35 0 0
New aluminium cuttings	110 0 0
Braziery copper	82 0 0
Gunmetal	83 0 0
Hollow pewter	240 0 0
Shaped black pewter	140 0 0
(Above all d.d merchant's yard).	

Metallurgical Coke.

Durham and Northumberland—	£ s. d.
Blast furnace	2 8 0
Foundry	2 13 0
Lancs., Staffs., Yorks, Notts., Derbyshire, Lincolnshire and Midland Counties—	
Blast furnace	2 10 6
Foundry	3 6 0
F.o.t. at ovens.	